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At the heart of the image





The Brazilian **free-tailed bat** will leave most birds in their dust → p17

# WELCOME



The deep sea might finally be about to **give up** its secrets. Right now, 95 per cent of our oceans are unexplored: our seas are more alien to us than the surface of our neighbouring planets.

The problem is that navigating our planet's darkest depths is a practical nightmare. For a start, we can't point a telescope at our seas to scout out what's down there, and actually visiting the bottom of the oceans presents an engineering challenge some consider more difficult than going to space. But there are tantalising treasures lurking for those willing to dive into the unknown.

Bizarre life forms living independently of the Sun's light offer clues to how life may have first taken shape on our planet. And they might even help us find out what life might look like out in the cosmos. Newly discovered species could offer up new drugs and chemicals that could transform science on the surface too. For example, a Nobel prize-winning glowing protein that lets us map out the functions of the body was first discovered in a jellyfish. Inevitably, private companies are also keen to see if they can dig up minerals at the bottom of the ocean, which could be used to build smartphones.

Whatever their motivation, new technology is now enabling aquatic explorers to go deeper and further than they ever have before. Head to p44 to find out more.

Enjoy the issue, and we'll see you in the new year!

*Daniel Bennett*

Daniel Bennett, Editor

## IN THIS ISSUE



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Ian, an anthropologist and evolutionary biologist, takes a look at the future of human evolution and answers whether natural selection still affects us today. → p76



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It's our planet's last unexplored frontier, but scientists are gearing up to explore the deep oceans. Marine biologist Helen gives us the low-down on these underwater pioneers. → p44



### COLIN STUART

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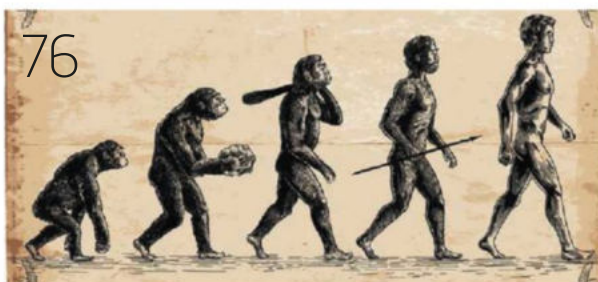
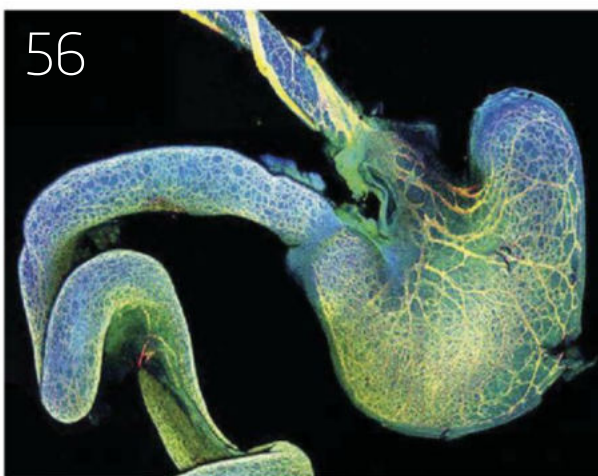
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## Going with the flow

MOUNT KILAUEA, HAWAII

USA

Now this really is a hot shot. The gently glowing lava flows of Mount Kilauea volcano, Hawaii are capped by the faint streak of a shooting star, the sprawling majesty of the Milky Way and a gleaming full Moon.

"What's special about the volcanoes of Hawaii is that they sit on a giant hotspot, which is the origin of the very islands themselves," says Prof Dougal Jerram, a volcano expert and BBC presenter. "A hot plume of material from deep within the Earth feeds the volcano, and as the Pacific plate slowly moves over this hot spot you get the chain of islands that form the Hawaiian archipelago."

Mount Kilauea is the most active volcano on Earth – its current eruption has lasted for more than 30 years. Its gently sloping landscape means that the incandescent lobes of lava which it produces are slow-moving but expansive.

"Each lobe breaks out from a previous one and flows like hot treacle, making a characteristic folded, rope-like texture on the surface, which is named by an Hawaiian word 'pahoehoe'," says Jerram.

PHOTO: MIKE MEZEUL II







## Mobile disco

### SINGAPORE

A tiny mirror spider, no more than 5mm across, scatters light through a Singapore forest thanks to a collection of small 'mirrors' on its abdomen.

This species is a lesser-known member of the genus *Thwaitesia*. Despite their blinged-up appearance, the spiders are actually masters of disguise. The mirrors provide camouflage by reflecting the surrounding environment, dispersing light like a disco ball and giving the spiders the appearance of water droplets lying on the plants.

"A spider that even an arachnophobe could love, these sequined or disco ball spiders reveal just how rich and diverse the spider fauna of the world is," says Prof Adam Hart, BBC broadcaster and entomologist at the University of Gloucester.

The silvery patches are made up of guanine crystals, a substance that also gives fish scales their shimmer and shampoo its shine. Though they look like solid shards, the 'mirrors' often change in size, retracting when the arachnids are threatened and swelling up when they relax.

PHOTO: NICKY BAY





# CREATE YOUR SPACE

Quality noise-cancelling headphones are ideal for tuning out the world and aiding concentration. But what should be on your playlist? Luckily, science has provided some handy tips



Trying to concentrate? Try upping the tempo. A study at the University of Toronto compared IQ test performance while students listened to two pieces of music. The first, by Mozart, was around 130 beats per minute (BPM), while the second, by Albinoni, was about 80 BPM. Participants reported improvements in mood while listening to the faster piece, and performed better on the test.



Concentrating to music is a bit of a Goldilocks situation: to find the sweet spot, you can't go too loud, or too quiet. Instead, you need to get it just right. A joint study by researchers at the Universities of Illinois, Virginia and British Columbia found that high and moderate volumes increased participants' ability to think abstractly, but found that higher volumes also decreased the brain's ability to process information.



One of the more obvious uses of music is to drown out conversation. Millions of years of evolution of our speech centres means we're really good at tuning into the human voice, and it's difficult to turn it off when we need to. Music with lyric can trigger the same distracting response, which is why it's probably best to opt for something instrumental – good news for techno, jazz, or classical fans.



White noise has long been touted as a relaxation and concentration aid, but recent studies suggest nature sounds can work just as well. Research has found that the vital quality to aid focus is randomness, but only within a certain range: too much randomness and it's distracting; too little and it becomes an overbearing drone. Researchers found the sound of a stream, wind blowing through trees or gentle rain to be ideal.



Of course, none of this is much use without a decent pair of headphones to put it to the test. Luckily, Sennheiser's new wireless PXC 550 are much more than that, thanks to best-in-class NoiseGard™ adaptive noise cancellation tech. It effectively removes the outside world, leaving you able to enjoy the ultimate sound experience, whether you're on your commute, at work, or relaxing to your favourite music. Even better, the PXC 550 have been designed to work seamlessly with CapTune, Sennheiser's premium music player and sound tuner app. Order yours today from [Sennheiser.co.uk](http://Sennheiser.co.uk) and at all good electronics retailers.

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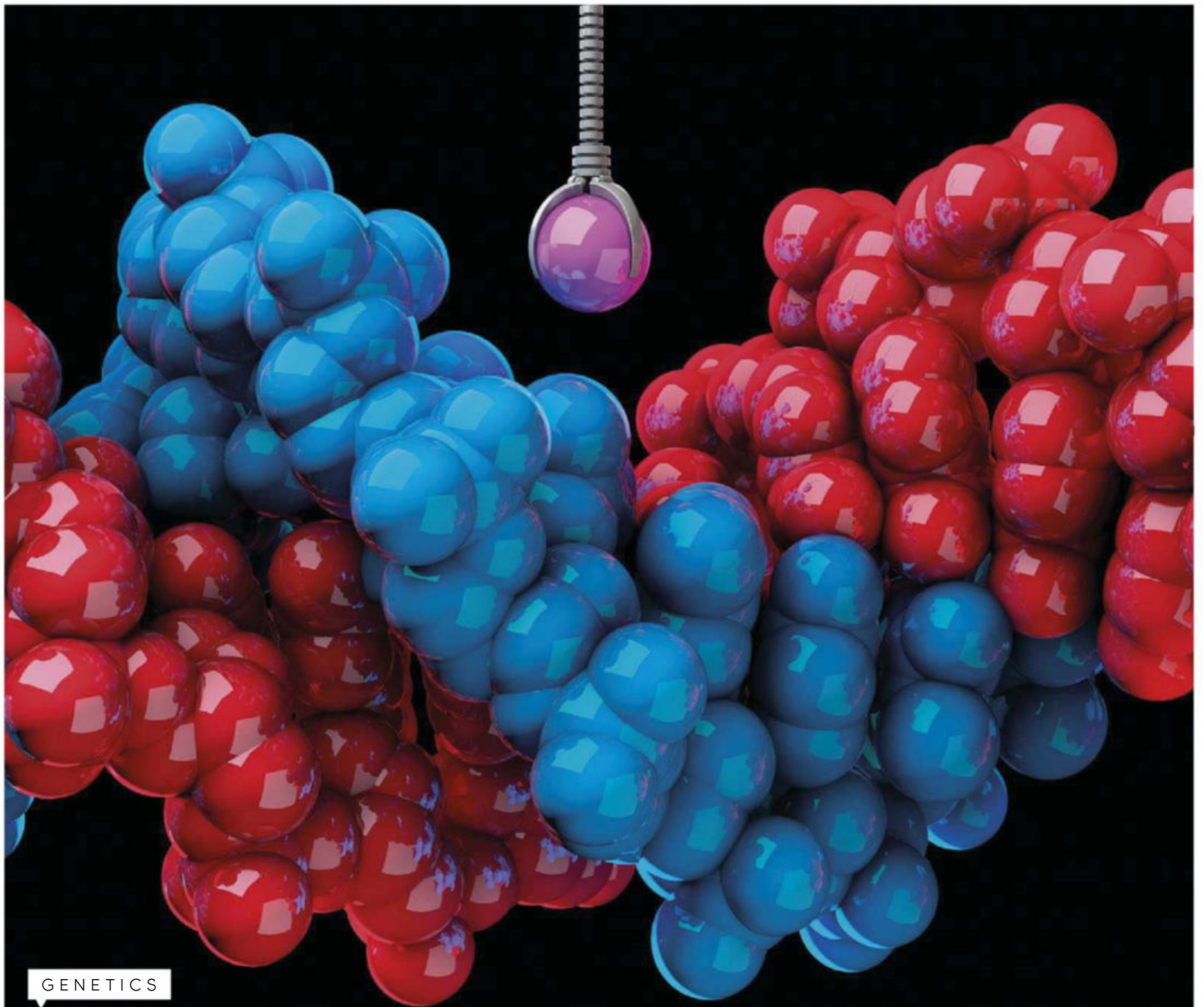


# DISCOVERIES

DISPATCHES FROM THE CUTTING EDGE

CHRISTMAS 2016

EDITED BY JASON GOODYER



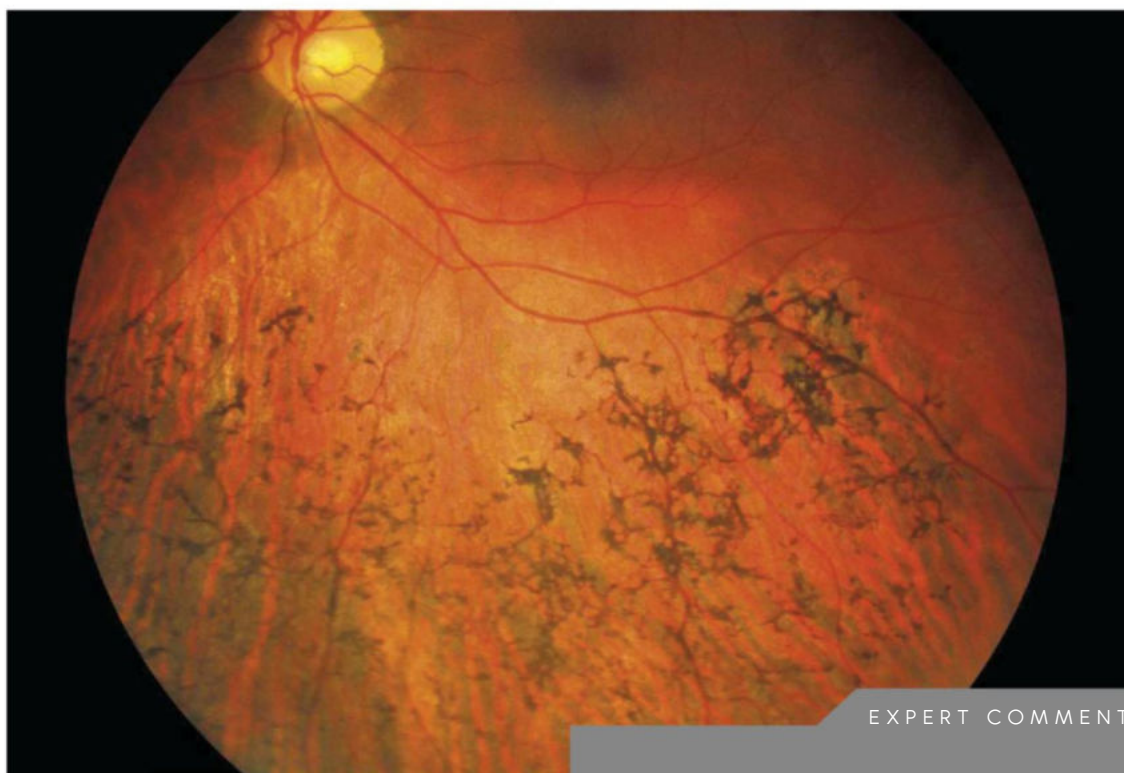
GENETICS

## Gene-editing breakthrough restores sight in blind rats

New technique could allow us to target disease at a genetic level



“WE NOW  
HAVE A  
TECHNOLOGY  
THAT  
ALLOWS US  
TO MODIFY  
THE DNA OF  
NON-DIVIDING  
CELLS”



ABOVE: The inside of  
a human eye with  
retinitis pigmentosa

In a breakthrough that's been described by researchers as the 'Holy Grail' of genetics, a team at the Salk Institute have successfully used gene-editing tool CRISPR to repair broken genes in the retinas of blind rats, partially restoring their sight. The same technique could be used to cure a range of genetic diseases, the researchers say.

Until now, DNA modifying techniques had only been successful in editing genes found in dividing cells, such as those in skin or the gut. However, most of our adult organs and tissues, such as the heart, brain and liver, are made up of cells that have stopped dividing, which makes it much harder to alter their DNA. This is the first time that researchers have been able to alter genetic material in such cells.

“We are very excited by the technology we discovered because it's something that could not be done before,” said researcher Juan Carlos Izpisua Belmonte. “For the first time, we can enter into cells that do not divide and modify the DNA at will. The possible applications of this discovery are vast.”

The team tested their technique on rats engineered to have retinitis pigmentosa, a genetic form of blindness affecting about 1 in 4,000 humans in which faulty DNA causes cells in the retina to die. The researchers introduced a functional copy of one of the genes that is damaged in retinitis pigmentosa into the eyes of blind three-week-old rats. When the rats were

EXPERT COMMENT

## Prof Robert MacLaren

*Professor of ophthalmology, University of Oxford*

“This is a significant advance. Retinitis pigmentosa is a genetic disease that causes blindness – it affects about 1 in 4,000 people in the UK.

“The particular rat strain used is missing some of the genetic code in cells of the retina. The cells die off and the rat becomes blind – similar to patients with the same gene defect. The researchers use gene therapy to correct the DNA in the rat retinal cells, leaving them with some vision.

“Researchers are now using this mechanism to correct gene defects. Clinical trials are a long way off because the CRISPR proteins may cut DNA at other sites, which may have untoward effects. Nevertheless, since ageing is defined as picking up DNA mutations, the ability to correct these mutations may in future provide us with a means of extending our lifespan, as well as treating many diseases that relate to ageing.”

eight weeks old, they were able to respond to light, and passed several tests indicating healing in their retinal cells.

“We now have a technology that allows us to modify the DNA of non-dividing cells, to fix broken genes in the brain, heart and liver,” said Izpisua Belmonte. “It allows us for the first time to be able to dream of curing diseases that we couldn't before.”

However, while the technique shows great promise, human trials are still a long way off.



## PALAEOLOGY

# DINOSAUR BRAIN IDENTIFIED FOR FIRST TIME EVER

This 'brown pebble' found by a fossil hunter in Sussex more than a decade ago has been confirmed as the first known example of dinosaur brain tissue.

The brain is thought to have belonged to a species closely related to the Iguanodon, a large plant-eating dinosaur that lived during the Early Cretaceous period, about 133 million years ago, and has many features in common with the brains of modern day crocodiles and birds.

Finding fossilised soft tissue, especially brain tissue, is very rare due to the conditions required to create it. The researchers say this piece is so well preserved as it was 'pickled' in an acidic, oxygen-deprived body of water shortly after its death, causing the soft tissue to become mineralised.

"What we think happened is that this particular dinosaur died in or near a body of water, and its head ended up partially buried in the sediment at the bottom," said

researcher David Norman. "Since the water had little oxygen and was very acidic, the soft tissues of the brain were likely preserved and cast before the rest of its body was buried in the sediment."

The team used a scanning electron microscope to identify strands of collagen, blood vessels and meninges (tough membranes that surround the brain) in the specimen. They also found networks of delicate capillaries that may belong to the brain cortex.

"As we can't see the lobes of the brain itself, we can't say for sure how big this dinosaur's brain was," said Norman. "Of course, it's entirely possible that dinosaurs had bigger brains than we give them credit for, but we can't tell from this specimen alone. What's truly remarkable is that conditions were just right in order to allow preservation of the brain tissue – hopefully this is the first of many such discoveries."

This small brown 'rock' is thought to be a fossilised chunk of dinosaur's brain



## IN NUMBERS

## 2,325

The number of exoplanets found to date by NASA's Kepler spacecraft.

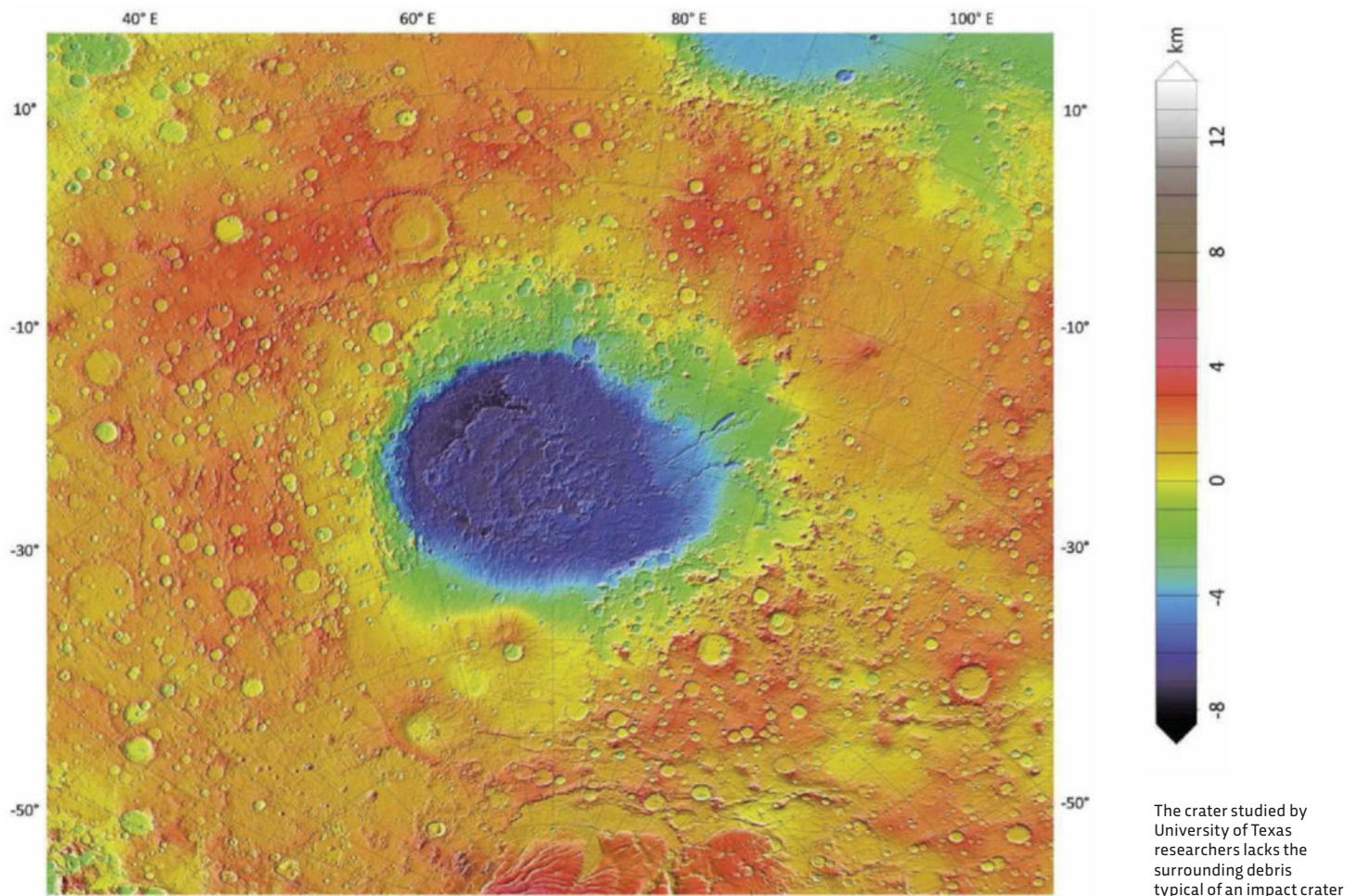
## 3.4°C

The amount by which the global average temperature is set to rise by 2100, according to the United Nations Environment Programme – a figure well above the 2°C many experts say is needed to limit the impact of climate change.

## 508

The number of breeding pairs of golden eagles found in Scotland by the RSPB, up from 442 in 2003. The figure means that the bird population is likely to return to historical levels.





## SPACE

## FUNNEL-LIKE CRATER MAY BE THE BEST PLACE TO LOOK FOR SIGNS OF LIFE ON MARS

It might not look like the most hospitable place to live, but this strangely shaped depression could have once been home to Martian life.

The crater is perched on the rim of the Hellas basin, in the southern hemisphere of the Red Planet, and was probably formed by a volcano beneath a glacier. It could have been a warm, chemical-rich environment well suited for microbial life, says Joseph Levy, a researcher at the University of Texas say.

"These landforms caught our eye because they're weird-looking. They're concentrically fractured so they look like a bull's eye. We were drawn to this site because it looked like it could host some of the key ingredients for habitability – water, heat and nutrients."

It first caught the researchers' attention in photos taken by the Mars Reconnaissance Orbiter, thanks to its similarity to 'ice cauldrons' – formations made by volcanoes

"THESE  
LANDFORMS  
CAUGHT OUR  
EYE BECAUSE  
THEY'RE  
WEIRD-  
LOOKING"

erupting beneath an ice sheet – found in Iceland. They then used pairs of high-resolution images to create detailed 3D models of the depressions that enabled in-depth analysis of their shape and structure.

"The big contribution of the study was that we were able to measure not just their shape and appearance, but also how much material was lost to form the depressions. That 3D view lets us test this idea of volcanic or impact," Levy said.

The analysis revealed the crater has an unusual funnel shape, and features a fracture pattern that suggests the ice has been melted away by volcanic activity. It also lacks the surrounding debris that would have been left by an asteroid impact. This means it may once have been host to liquid water and nutrients – elements thought to be required for the existence of life.

PHOTO: NASA



## ZOOLOGY

# TINY BAT SMASHES FLIGHT SPEED RECORD

Meet the Brazilian free-tailed bat, the fastest horizontal flier in the animal kingdom. Researchers at Germany's Max Planck Institute have clocked the small mammal speeding through the air at more than 160km/h (99mph), smashing the previous record of 111km/h (69mph) held by the common swift. Key to the bats' speed are their aerodynamic, projectile-like bodies, light bones and long, narrow wings.

Peregrine falcons hold the overall speed record reaching around 390km/h when diving, but they can only manage 90km/h during horizontal flight.

"Initially, we could hardly believe our data, but they were correct: at times, the female bats, which weigh between 11 and 12 grams, flew at speeds of over 160 kilometres per

hour – a new record for horizontal flight," said researcher Kamran Safi.

The team clocked the record-breaking speed by attaching small radio transmitters to the bats' backs and then following their flights using a mobile receiver on board a small aircraft. "It was not easy for the pilot

to follow the fast-flying animals so that we could localise them accurately and measure their flight path continuously," said researcher Dina Dechmann. "External factors like landscape and tailwinds cannot explain these results, as they had no impact on the maximum speeds."

## THEY DID WHAT?!

# RATS TICKLED TILL THEY GIGGLED

### What did they do?

A team at the Humboldt University of Berlin set up a specially designed 'tickling area' and monitored the brain activity and ultrasonic squeaks of rats while they were being tickled.

### What did they find?

Rats have previously been observed to give out high-pitched, laughter-like squeaks when being tickled. The Humboldt team confirmed this, finding

the laughter response in the rats' brains is very similar to that of humans. They also found that if they were put in stressful situations, such as being under a bright light, the rats didn't chuckle at all.

### Why did they do that?

The findings may help to shed light on how negative and positive experiences are processed in the brain and ultimately affect our behaviour, the team says.





## ZOOLOGY

# CREATIVE COCKATOOS DESIGN AND MAKE THEIR OWN TOOLS

When cockatoos want to tool up, they get creative. Researchers at Oxford University have observed Goffin's cockatoos cutting out tools from a sheet of cardboard and using them to retrieve out-of-reach nuts, suggesting that the birds can fashion objects with a specific design in mind.

Previously, the team had observed one bird, Figaro, biting long splinters out of the wooden beams of his cage and using them to rake pieces of food that lay beyond his reach. This was doubly surprising as Goffin's cockatoos are not known to use tools in the wild – they don't even use twigs to make nests.

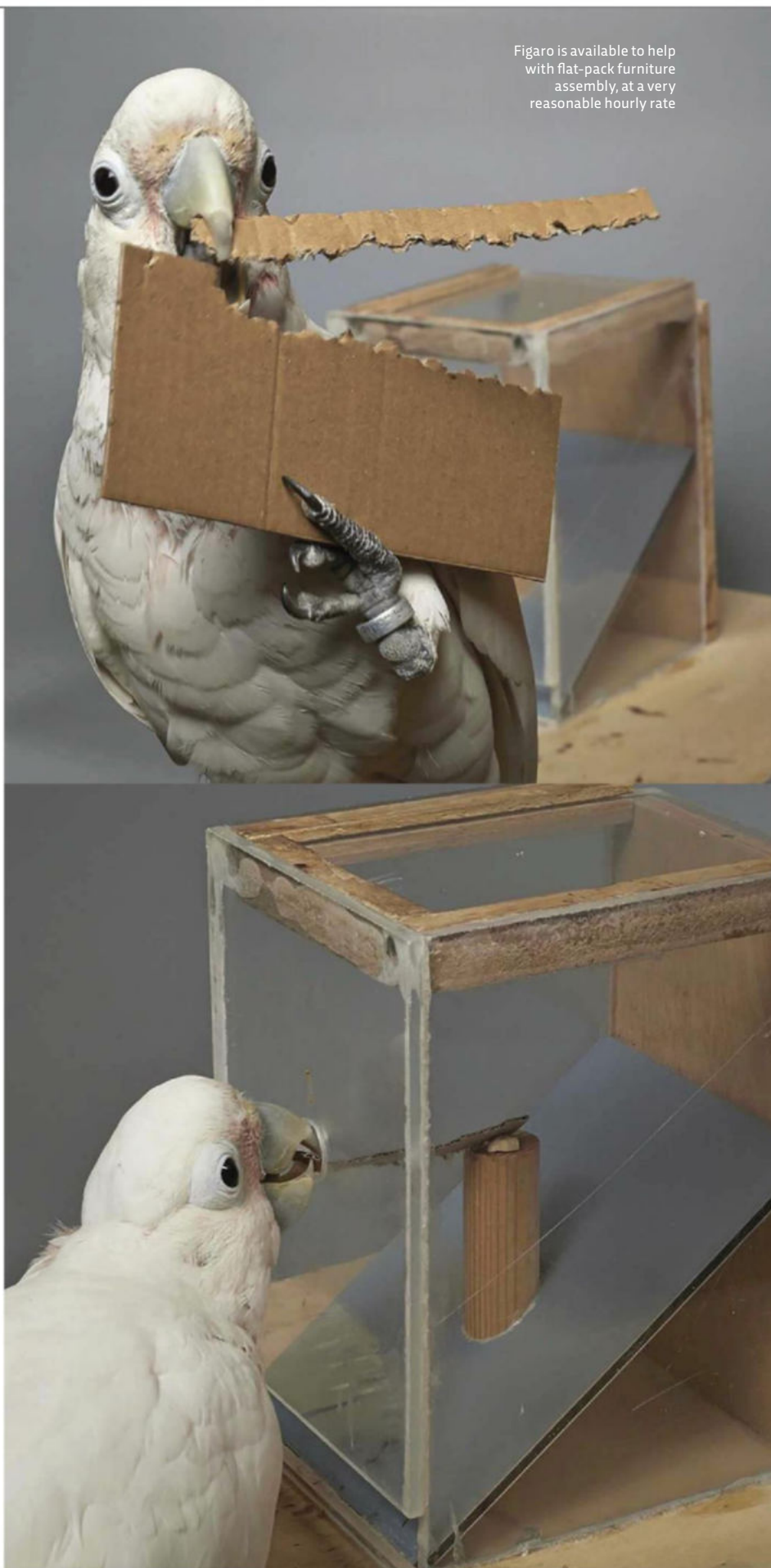
However, as wood naturally splits into long, narrow splinters, it was impossible to say whether the bird was aiming to make a long raking tool or if the whole thing was just a happy accident.

To test this, the team placed a piece of food a few centimetres beyond a circular hole in the transparent wall of a box and gave Figaro and three other birds four different materials to produce suitable tools: larch wood, leafy beech twigs, cardboard and beeswax. Figaro and one other bird were able to produce effective tools with everything but the beeswax.

"To us, the tools made from cardboard were the most interesting ones, as this material was not pre-structured and required the birds to shape their tools more actively," said researcher Alice Auersperg. "They succeeded by placing a large number of parallel bite marks along the edge of the material like a hole punch, using their curved upper beak to cut the elongated piece out of the cardboard block after reaching a certain length."

The findings suggest that the birds are capable of individual creativity and problem-solving, say the researchers.

Figaro is available to help with flat-pack furniture assembly, at a very reasonable hourly rate







## NEUROSCIENCE

## NEW IMAGING TECHNIQUE PROVES WE ALL HAVE A UNIQUE 'BRAINPRINT'

It seems our brains really are all wired up differently. The structural connections in our brains are so unique to each individual that they can be used to identify us like fingerprints, a team at Carnegie Mellon University has found.

The researchers scanned the brains of nearly 700 volunteers, using a new method of non-invasive MRI that enabled them to capture the brain's 'connectome' – the point-by-point connections that join together all of the white matter – in much more detail than ever before.

They discovered that even identical twins only share about 12 per cent of structural connectivity patterns, and that the brain's unique local

connectome is sculpted over time, changing at an average rate of 13 per cent every 100 days.

"This confirms something that we've always assumed in neuroscience: that connectivity patterns in your brain are unique to you," said Timothy Verstynen, one of the research team involved. "This means many of your life experiences are somehow reflected in the connectivity of your brain. Thus we can start to look at how shared experiences, for example poverty or people who have the same pathological disease, are reflected in your brain connections, opening the door for potential new biomarkers for certain health concerns."



### CHUBBY DADS

Ever catch a glimpse of your dad bod in the mirror and despair? Well, don't: researchers at Yale University have found that older dads who pile on the pounds, due to decreasing testosterone levels after fatherhood, live longer and have stronger immune systems than their buffer, childless counterparts.

### BEER DRINKERS

Make mine a pint! A team at Pennsylvania State University has found that drinking a beer a day can help to lower harmful cholesterol in the blood stream. Don't get too tipsy though – the effect is reversed in heavy drinkers.

## GOOD MONTH

## BAD MONTH

### CLINGY MOTHERS

It's time to cut the apron strings. Children who go to nursery rather than staying at home with their parents have more talking, social and motor skills, researchers at Oxford University have found.

### BEEFCAKES

The phrase "all show and no go" evidently has some truth to it. A study published in *Muscle And Nerve* has found increases in muscle size due to working out are not directly related to muscle strength.





## SPACE

## DID SATURN STEAL ITS RINGS FROM INTRUDING DWARF PLANETS?

Thanks to its distinctive pattern of rings, Saturn is one of the most recognisable and spectacular sights in the Solar System. But exactly how the gas giant's signature halo got there has always been something of a mystery.

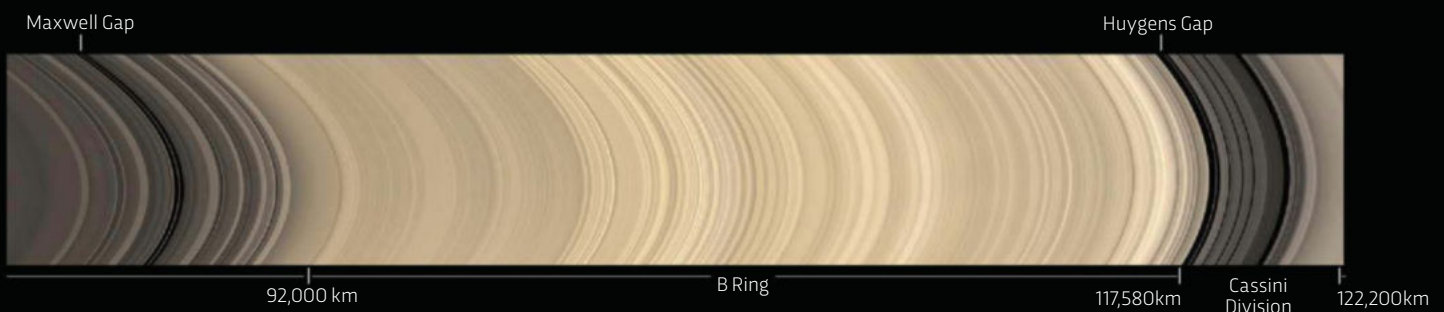
Now, researchers from Japanese and French universities have found that the chunks of ice and rock that make it up may have come from collisions with thousands of Pluto-like bodies.

Around four billion years ago, the orbits of the giant planets in the Solar System – Jupiter, Saturn, Uranus and Neptune – became unstable. It is thought that this created a change in the gravitational pull on thousands of Pluto-sized

bodies in distant orbit around the Sun, drawing them into the deeper into the Solar System where they collided with the planets. This could explain why there are so many craters on the surface of the moon.

By modelling this event using supercomputers at the National Astronomical Observatory of Japan, the researchers found that the fragments broken off from these planetary collisions may have been captured by the giant planets and drawn into orbit around them. Further collisions between these fragments could then have broken them down even more, leading to the formation of the rings we see today.

BELOW: Saturn's rings consist of 99.9 per cent pure water ice, with a total mass of  $3 \times 10^{19}$  kg



PHOTOS: NASA, LORI SANDERS/HARVARD



## DINOSAURS

# 'MUD DRAGON' FOSSIL DATES BACK TO DINOSAURS' LAST DAYS

This is *Tongtianlong limosus*, or 'muddy dragon on the road to heaven' – a new species of feathered dinosaur that was recently unearthed near Ganzhou in southern China.

The fossil was found by researchers from the University of Edinburgh and the Chinese Academy of Geological Sciences on a construction site where a new school was being built, lying on its front with its wings and neck outstretched. It's believed the dinosaur may have died in this pose after becoming stuck in a pool of mud around 70 million years ago. Despite being accidentally subjected to a dynamite blast, it is almost complete and remarkably well preserved.

*Tongtianlong limosus* belonged to the oviraptorosaur family. Oviraptorosaurs were flightless, feathered creatures that are thought

to have been one of the last groups to flourish before an asteroid impact killed off all the non-bird dinosaurs, some 66 million years ago. It walked on two legs and had a prominent crest of bone on its head, much like that seen on modern-day cassowaries.

"This new dinosaur is one of the most beautiful, but saddest fossils I've ever seen," said the University of Edinburgh's Steve Brusatte. "But we're lucky that the Mud Dragon got stuck in the muck, because its skeleton is one of the best examples of a dinosaur that was flourishing during those final few million years before the asteroid came down."



ABOVE: The Mud Dragon, as it's been nicknamed, was covered in feathers but couldn't fly  
BELOW: The *Tongtianlong limosus* specimen is remarkably well preserved



## WHAT WE LEARNED THIS MONTH

### FOOTBALL REFS HAVE SUPER VISION

Belgian researchers have found that top-level football referees have enhanced visual perception that makes them better at spotting foul play. It seems that the ref doesn't need glasses after all.

### CATCHY SONGS SHARE COMMON MELODIES

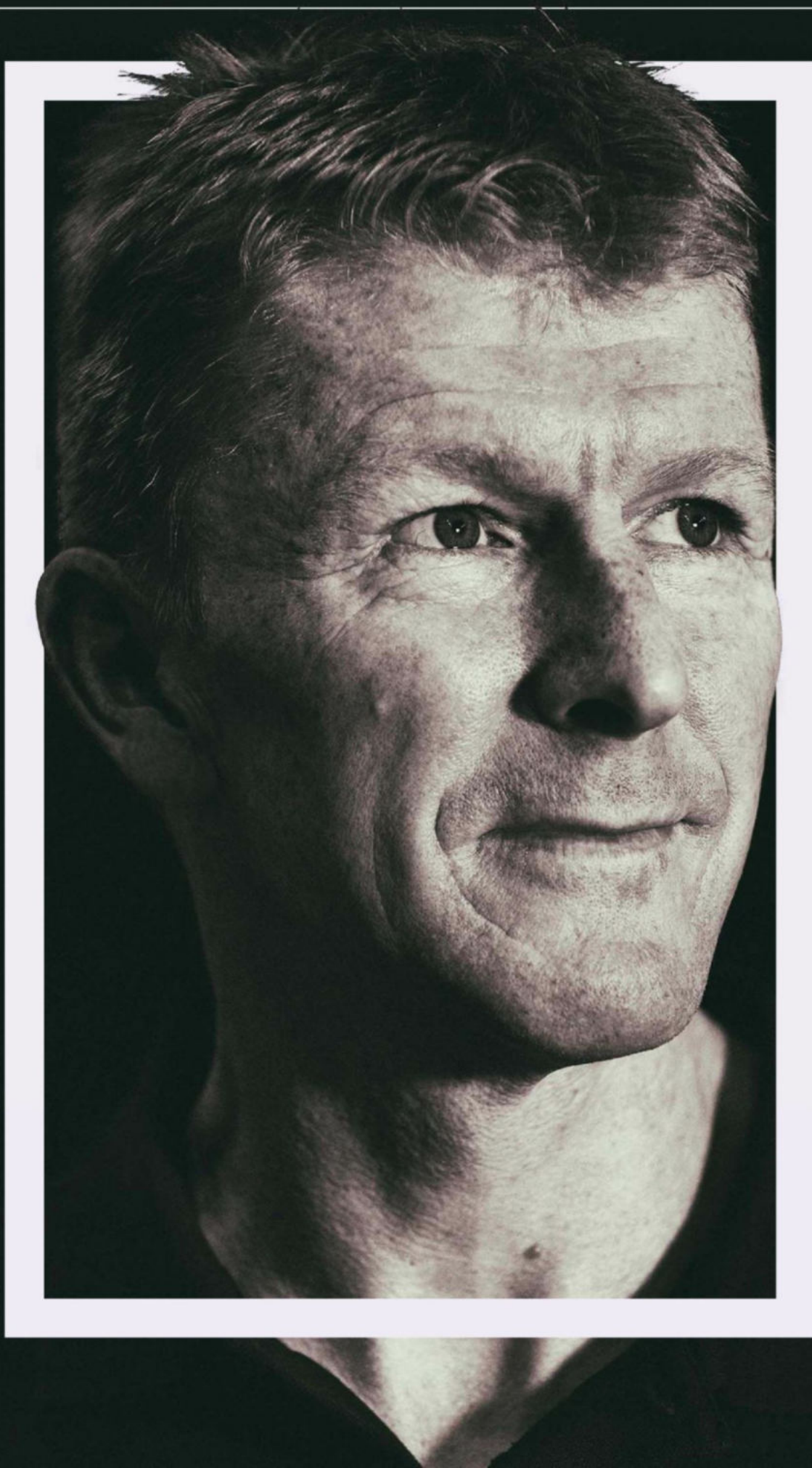
A team at Durham University has found the catchiest pop songs feature motifs that rise then fall in pitch, unusual melodic leaps, and lots of repetition. Topping their list of songs that fit the bill was *Bad Romance* by Lady Gaga. Rah rah, ah-ah-ah...

### SWIFTS SPEND MOST OF THEIR LIVES IN THE AIR

The common species of swift flies for 10 full months of the year, landing only to breed, a team of Swedish researchers has found. It's the longest known time spent on the wing by any bird.

### WE ARE HARD-WIRED TO PREFER RED FOOD

It looks like all those hours spent unsuccessfully trying to convince your little 'uns to eat their greens might have been a waste of time. A team in Trieste, Italy has found we have a natural preference for red food due to its higher calorific content.





## THE FOCUS INTERVIEW

# DOWN TO EARTH

A year ago this month, **Major Tim Peake** blasted off to spend half a year aboard the International Space Station. Now, six months after his return to Earth, he chats to us about his experiences in space

WORDS: **STUART CLARK**

Astronaut Tim Peake became a national hero on 15 December 2015 when he headed off into space for a six-month visit to the International Space Station (ISS). For years, the UK government had been staunchly against contributing money, and therefore astronauts, to the European Space Agency (ESA).

Peake's six months aboard the ISS were an unqualified success in every sense. He performed extraordinary science and inspired millions of people, young and old, through his tweets, photos and videos. Now that he's back on Earth, spreading the message that human spaceflight is a good thing for the UK is top of his priorities.

## How did you find returning to Earth?

There's definitely an adjustment period. I almost see it as two: a short-term adjustment and then a longer-term adjustment. The shorter term is obvious because when you first stand on Earth, your vestibular [balance] system is in overdrive and it's quite obvious that your body has got some serious adjusting to do. Any head movement from side to side feels very disconcerting, and so does standing up or sitting down. When you walk you have your legs a little bit wider apart and you are very careful not to turn your head as you are walking. But that goes in about two to three days. It's remarkable to watch your body progress. After two to three days everything is pretty much normal. You can balance, and walking starts to be okay. I was in the gym on the

***"We could smell this Earth-y smell. Sitting on the Kazakhstan Steppes... it was powerful"***

running machine and lifting weights three days after getting back, and was feeling pretty okay.

Then you're into the second phase, which is more gradual. Even now, three months on, I still don't feel at the peak fitness I was before the mission. I think that'll take another couple of months.

## What was one of the first things you noticed on returning to Earth?

The smells! I'd experienced this before, when I lived in a cave for seven days as part of ESA's astronaut training. Training in a cave helps you deal with isolation and working in a small group. I remember coming out of the cave and thinking that it was like someone had turned on full contrast on the television: colours were so bright and smells were

so intense. Your senses had been deprived for so long and then suddenly they were hit by this massive overload.

Coming out of the capsule after landing was a bit similar but the first smells that hit you are fairly unpleasant. The capsule has been burning up at 2,000°C, all of the absorbing and ablating material is now crispy, the plasma has scorched all the windows, and quite often the grass gets set on fire. So the first smells are this burning, scorched odour. Once we got carried out in the chairs, then we could smell this really Earth-y smell, and the grass. Sitting on the Kazakhstan Steppes... it was powerful.

## Science was a big part of your mission. What were some of the experiments that you performed aboard the ISS?

Over the six months, my crewmates and I performed between 250 and 300 experiments, a lot of which were from the physical sciences. There were some really great experiments, looking at flame combustion in microgravity for example – wonderful experiments! The problem from an astronaut's point of view is that we don't tend to have a huge amount of interaction with those experiments. We set them up, we get them running and we ensure that the results go back to Earth, to the experts on the ground.

The experiments that we have much more attachment to are the life sciences because they are the experiments that are being done on our bodies – we are ●

RIGHT: A fresh fruit arrival is greeted with delight by Tim Peake on the ISS

the guinea pigs for those experiments. I volunteered for about 25 of them. For the first time, we used the airlock on the ISS as a hyperbaric chamber.

Hyperbaric chambers can have their pressures adjusted. In this experiment, the pressure in the airlock was altered to simulate the conditions on a Moon base. We wanted to investigate what the effects were of airway inflammation in space, by measuring nitric oxide in our exhalations. That's a technique that has been used on Earth before but never in space, and microgravity does some strange things to the body that allow us to learn more about inflammation of the airways, to help asthma sufferers back on Earth. That was a really interesting experiment with lots of participation.

Virtually every part of my body was analysed: blood, saliva, urine and faecal samples were quite regularly being taken and analysed. My cardiovascular system was looked at with ultrasound to see how it was changing. Our eyesight also changes in space, which we've only discovered quite recently. So there was a lot of emphasis on understanding why we get short-sighted when we go into space. We see this change in 60 per cent of astronauts, and in 20 per cent of them it does not recover once they return to Earth. So there are very interesting experiments in space.

#### Did you have any scary moments on the ISS?

I hate the word 'scary', you know. I've been a test pilot for 18 years and part of the job is looking at risk, and risk mitigation, and making sure that you are not scared. If you're scared then something has gone seriously wrong.

Of course there are moments of apprehension – you are doing a high-risk job. For example, our docking didn't go quite according to plan. Our automatic system had failed and we had to have two manual attempts. But thankfully we

had Yuri Malenchenko, a very experienced cosmonaut, at the controls. He had an extremely difficult docking to do in poor lighting conditions because we crossed the terminator from day to night. We were all working hard during that docking.

#### Why do you think human spaceflight is so important?

Exploration drives innovation. I think in our nature we are genetically designed to explore: to push our boundaries and reach out. Exploration is at the heart of that driving passion for many people. And you also challenge industries to be more innovative, to come up with better, lighter, stronger materials, and faster propulsion techniques.

Exploration is a great driving force for growth and innovation, and you have to have humans in the loop to do that to make it exciting and to use our ingenuity. Computers, robotics, and artificial intelligence are growing exponentially. It is exciting, but we are still many years away from having a computer or an artificial intelligence system that has the same kind of



***“I enjoyed the launch more than I thought I would. It is just foot-to-the-floor power. The schoolboy in me came out smiling most of the way through that”***





LEFT: Tim Peake visited 10 Downing Street shortly after arriving back to Earth

ingenuity and the thought processes of a human brain, and that has the emotional capacity of the human brain.

#### How has spaceflight changed you?

It is difficult to say how it has changed me. I haven't noticed any large change in myself, my personality or my character. But then, having said that, it is impossible for anyone to live off the Earth for six months, and be looking down at the planet every day, and not be changed by that experience. It's certainly given me a new perspective on our home planet.

I think I have always been a fairly calm, level-headed person, but if anything going up in space shows you that we are a tiny oasis of life in a vast blackness of space. And it is hard to describe just how black space is. When you see planet Earth in that perspective, it puts things into proportion.

#### Which was more adrenaline-filled: launch or landing?

That's a tough question. I enjoyed the launch much more than I thought I would. The feeling of acceleration was

much more addictive. It is just foot-to-the-floor power, and acceleration up to 25 times the speed of sound. Yeah, that was probably the more exciting. The schoolboy in me came out smiling most of the way through that.

The re-entry and landing were much more dynamic. A lot more can go wrong during the landing. We have to be very engaged. Clearly things can go wrong in the launch, but if they do then they tend to go catastrophically wrong and the automatic systems to protect the crew will either work or not work.

On landing, we have an engine burn to do, and many things can go wrong with that. So then there are all the subsequent procedures that we would have to do if the landing were to go wrong. That was all exciting, very dynamic and fun, but for pure exhilaration and excitement, launch was the one.

#### What's next for you? Is it too early to say whether there is another trip coming up?

Right now it's too early to say. When I joined up in 2009, there were six of us. We were told that there were only five flights, and the last one was in 2020.

Well, ESA is extremely good at getting its astronauts flown, and here we are in 2016 with Thomas Pesquet launching in two months, and he's the last of that class of six to fly. So to sit here and say I won't have another mission would be fairly foolish right now. Already Alex Gerst of my class has been re-assigned to his second mission. He flew in 2014.

There will be another assignment taking place next year, so hopefully one of our class will get that. It's in ESA's interest to have us fly again because it takes a lot of time and money to train an astronaut. But also politics and funding has a huge part to play in that. We have a ministerial meeting coming up at the end of this year and we hope to see the UK continue its participation in the International Space Station.

#### Mars or the Moon?

Both in incremental order. Coming from a test pilot background, you need to do things in incremental steps and the Moon is such an obvious incremental step to Mars. We would learn so much, not just to go to the Moon for the sake of going to Mars, but to go to the Moon to set up a permanent habitation there. Instead of people going to stay for six months on a space station, we will see people going for six months or year-long stays on a Moon base, doing research and learning how to live on another terrestrial body. And that really paves the way for how we then do a Mars trip.

A Mars trip is going to be really technologically challenging. We will learn a lot by going to the Moon. I think going to Mars first, and bypassing the Moon would be a big step and it might not actually be the best way to do it. 🚀

#### DISCOVER MORE

To watch videos of Tim Peake in space, visit [bit.ly/tim\\_peake\\_vids](http://bit.ly/tim_peake_vids)

# 2016

A detailed image of the Juno spacecraft, showing its central body and three large, rectangular solar panel arrays. The spacecraft is positioned diagonally across the frame, with the solar panels extending outwards. The background is a dark, starry space.

Juno was launched in 2011, and reached Jupiter this year

## WASN'T ALL BAD

**Thanks to outbreaks of Zika and MERS, the deaths of David Bowie, Prince and Harambe, and untold other tragedies, 2016 has been a bit of a stinker. But keep your chin up, here's our pick of the five biggest breakthroughs made this year**



## SPACE

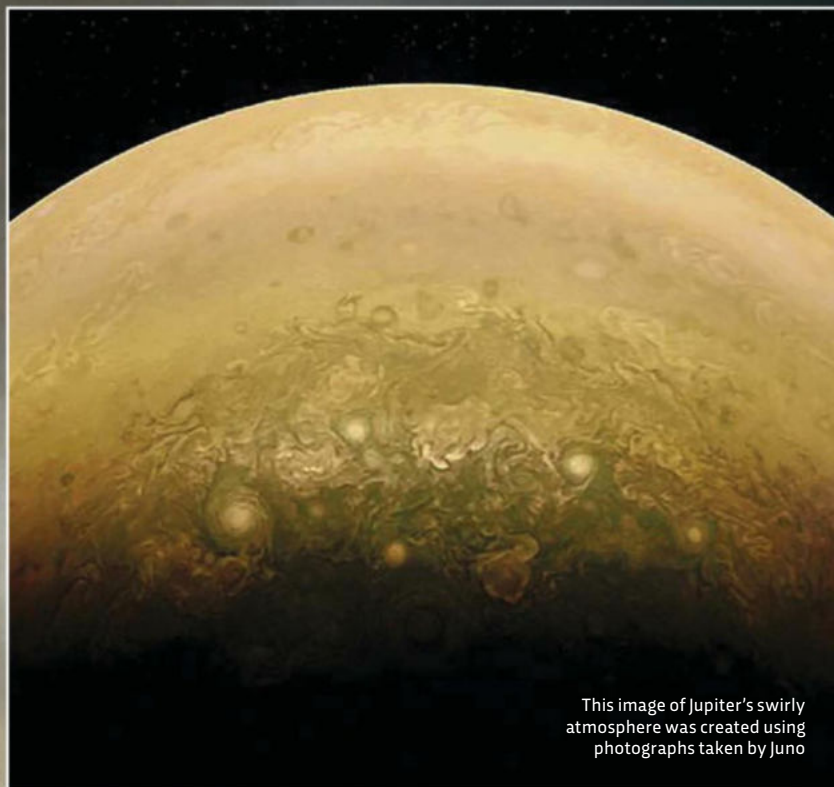
## JUNO MADE IT TO JUPITER

In July, NASA's Juno space probe completed its five-year journey to Jupiter. A month later the probe successfully executed its first flyby of the gas giant, travelling at more than 200,000km/h and passing within 4,200km of the planet's swirling clouds.

Scientific instruments onboard the space probe are designed to measure the planet's magnetic

field, atmospheric composition and landscape. At the time of writing, Juno has so far beamed back stunning pictures of Jupiter's poles, aurorae, and violent atmospheric storms.

The probe is scheduled to complete a total of 36 flybys before finally plummeting into the planet's surface at the end of its mission in February 2018.



This image of Jupiter's swirly atmosphere was created using photographs taken by Juno

## NEUROSCIENCE

## PARAPLEGICS TRAINED TO WALK AGAIN

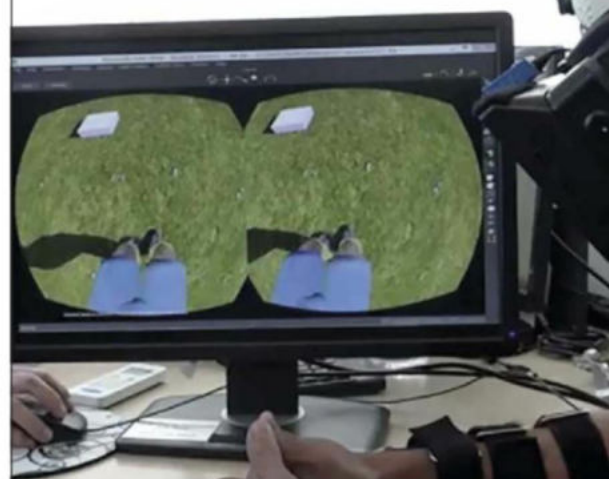
Scientists based at the Walk Again Project, in São Paulo, Brazil, announced in August that they were able to train eight patients with spinal cord injuries how to move their legs using robotics and virtual reality.

The team fitted the patients with electrode caps that could read the motor commands produced by their brains. They found that when they asked the patients to think about moving their legs no signals were produced. But by hooking them up to a VR walking simulator, the team was able to retrain the patients' brains to 'remember' how to use their legs, despite some of them being paralysed for more than 10 years. The most successful patient is now able to drive, and can walk using a frame.

The effect is likely to be due to the brain reorganising itself during the training and generating new electrical commands to send to the remaining nerves in the legs, the researchers say.

The team is now planning to conduct a new trial on patients who have suffered recent spinal cord injuries to see whether quicker treatment can lead to faster or better results.

VR isn't just for gaming – it has helped paraplegics learn how to walk again



## PHYSICS

## LIGO DETECTS GRAVITATIONAL WAVES

One hundred years after they were first predicted by Albert Einstein's General Relativity, gravitational waves were directly detected for the first time ever by researchers at LIGO (Laser Interferometer Gravitational-Wave Observatory) in February.

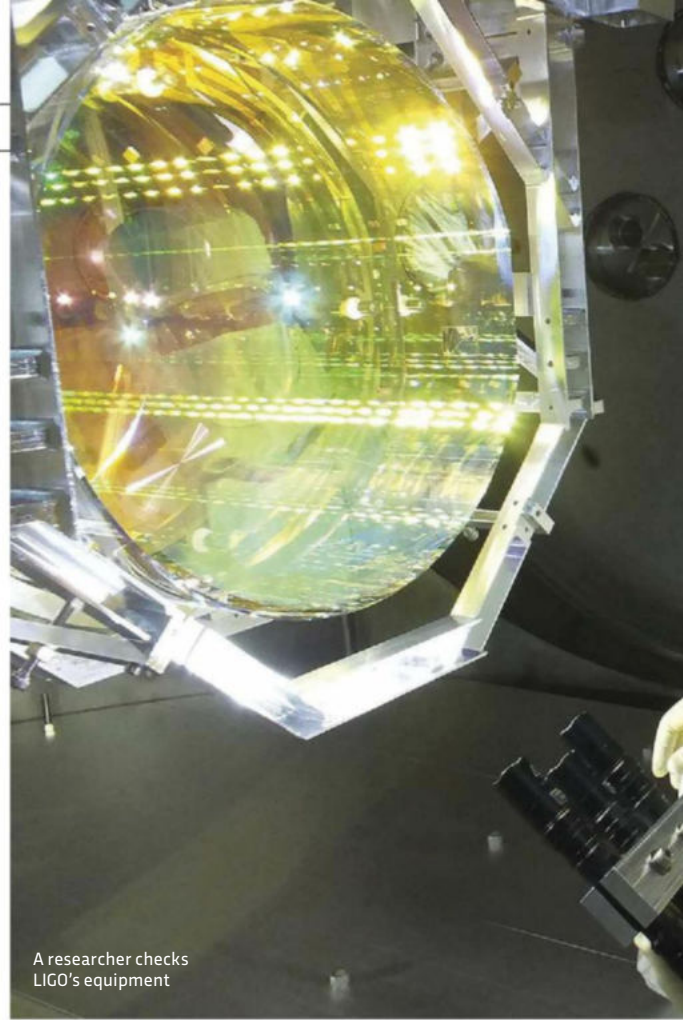
Gravitational waves are ripples in the fabric of space-time generated by violent events such as the collision of massive objects like black holes. They travel across the Universe stretching and squeezing space-time as they go. It took so long to find them because their effect is so weak – even Einstein doubted we would ever be able to make an instrument

sensitive enough to pick them up.

The waves observed by the team were generated by the collision of two black holes, about 29 and 36 times the mass of the Sun, which occurred 1.3 billion light-years away, meaning they have taken 1.3 billion years to reach as gravitational waves travel at the speed of light.

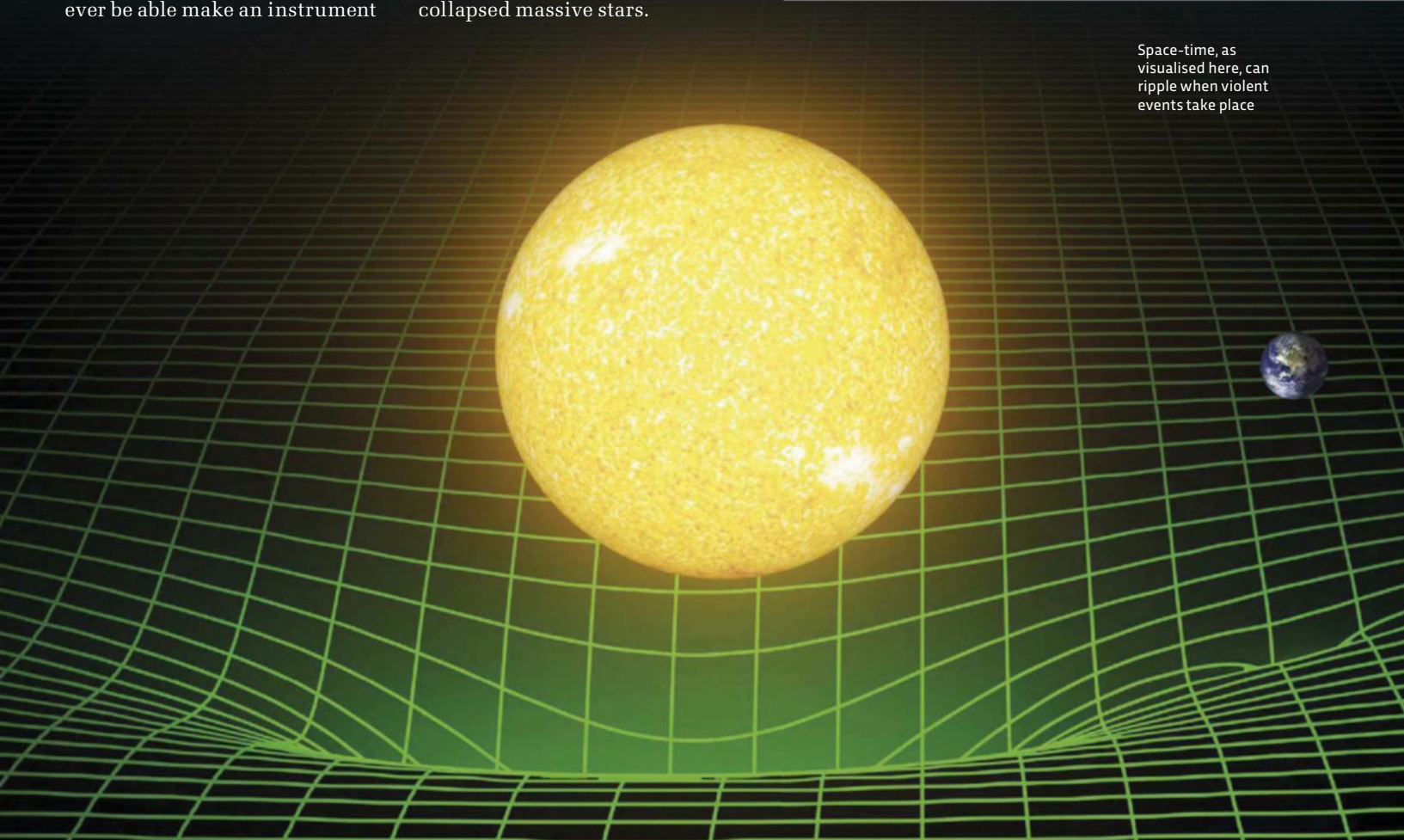
In June, the team announced they had observed gravitational waves for a second time, resulting from a collision between another pair of black holes. These ones were smaller, at 8 and 14 times the mass of the Sun, and located 1.4 billion light-years away.

The observatory is currently partway through a second, more sensitive run, looking for gravitational waves generated by the mergers of neutron stars, the incredibly dense cores of collapsed massive stars.



A researcher checks LIGO's equipment

Space-time, as visualised here, can ripple when violent events take place







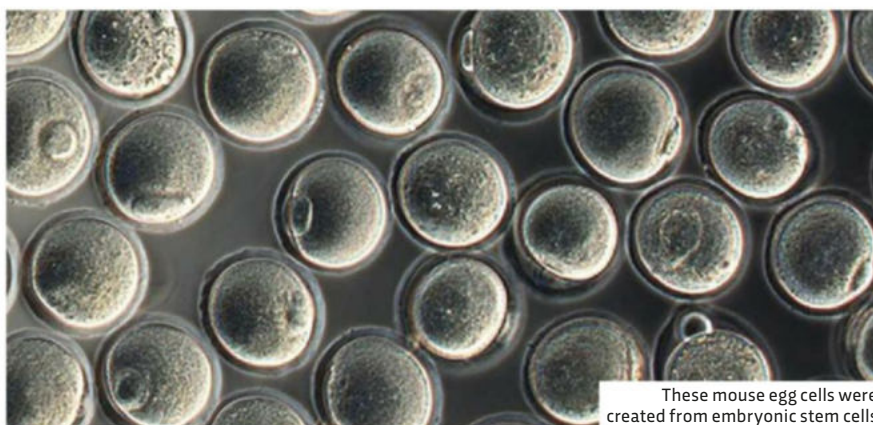
## PALAEOONTOLOGY

PREGNANT *T. REX*  
FOSSIL IDENTIFIED

Determining the sex of a dinosaur fossil is incredibly difficult as bones tell us very little about the animals' sexual characteristics. However, this year, a 68-million-year-old *T. rex* fossil became one of the first to be definitively identified as female thanks to the discovery of its medullary tissue – material found within a bone that supplies the calcium to create eggshells in pregnant females.

The fossil was originally excavated from Montana's Fort Peck Lake in 2003. Researchers suspected that the specimen's femur contained medullary bone but they were unable to send it for chemical analysis. But a tissue analysis carried out in March found that the sample contained keratin sulphate, a substance not found in other types of bone. The researchers also compared the sample to medullary tissue taken from modern ostriches and chickens and found similarities in composition and structure.

Identifying the dino as female will help the scientists to identify further characteristics that differ between sexes, and may even offer an insight into the evolution of egg-laying in modern birds.



These mouse egg cells were created from embryonic stem cells

## BIOLOGY

HEALTHY MICE BORN  
FROM LAB-GROWN EGGS

Another world first was announced in October, when Japanese researchers reported that they were able to raise healthy mouse pups from eggs created in the laboratory using stem cells.

The team, led by Katsuhiko Hayashi at Kyushu University, took skin cells from the tails of adult mice and transformed them into induced pluripotent stem cells. These are cells that have been genetically modified to behave like embryonic stem

cells, which are capable of forming any adult cell type.

The team then treated these stem cells with growth factors and hormones taken from mouse ovaries to coax them into growing into eggs, before fertilising them using IVF and implanting them into the wombs of living mice.

Though the method has so far only been proven in mice, and even then only 11 of the 300 embryos implanted resulted in successful births, it could one day help infertile human couples to have kids without the need for egg donors, the researchers said.



Substances in bones can help scientists to sex dinosaur fossils



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**'APPINESS'**

*Since its launch in 2006, the Tefal ActiFry has helped over 8 million households make guilt-free chips with just one spoonful of oil. Now, over a decade later, Tefal has once again changed the way we cook with the introduction of its first connected appliance, the ActiFry Smart XL.*

Controlled via Bluetooth and a dedicated app (**My ActiFry**, available on **Google Play** and the **App Store**), you can wirelessly send more than 200 recipes straight to your low fat fryer. The new Smart Technology automatically adapts the cooking to your chosen recipe.

Simply select your recipe on the app and be guided through every step. It will even tell you when and where to place ingredients inside the **ActiFry** for the best results.

Select favourites, create shopping lists and share recipes with friends and family, the **My ActiFry** app unlocks the full potential of the **Smart ActiFry**.

With **ActiFry Smart XL** it's not just chips (even though they still taste great), now you can do so much more. Cook delicious chilli con carne, creamy risottos and even crispy home made chicken nuggets - made from scratch.

[tefal.co.uk/actifry-smart](http://tefal.co.uk/actifry-smart)

**Actifry® smart XL**





**Tefal**  
Ideas you can't live without.

**COOK4ME** connect

*Continuing this revolution in home cooking is the Cook4Me Connect. This new one pot wonder allows you to control the device from your smartphone or tablet.*

The kitchen appliance comes with 50 pre-programmed recipes (starters, mains and desserts), which include step-by-step guides, detailing the exact ingredients and measurements for each dish, via its built in LED display.

More convenient and versatile than ever, **Tefal's Cook4Me Connect** comes with Bluetooth connectivity and a dedicated app for your smartphone or tablet (**My Cook4Me**, available on Google Play and the App Store). Where you can access a digital library of over 100 recipes that sync straight to the appliance.

This all-in-one pot solution is perfect for families who want homemade quick and tasty meals or those who don't want to spend hours in the kitchen. You can cook an entire meal in just one pot, and enjoy the added benefit of hassle-free cleaning afterwards.

It's also a great assistant for the more insecure cook who still wants to experiment and values the importance of preparing fresh and healthy meals.

With six cooking functions: pressure cook, steam, brown, simmer, slow cook or reheat, it's an excellent time saver too! Most recipes can be cooked in 15 minutes or less!

[tefal.co.uk/cook4me-connect](http://tefal.co.uk/cook4me-connect)

Both of these breakthrough launches took place this year but there's a lot more to come in 2017, as **Dominik Pytel, Groupe SEB Marketing Director** says, "This is our first foray into the world of connected appliances and we have ambitious plans in place to further develop this market in the UK."

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'MY COOK4ME' APP



# RAZER™ RAIJU GAMING CONTROLLER



## DESIGNED FOR ESPORTS

Engineered to take your console gameplay to the next level, the **Razer Raiju for PlayStation® 4** features four additional fully-programmable buttons, a weight and shape that's been fine-tuned, and a Quick Control Panel. Incredibly durable and extensively tested by esports athletes, dominate your game with this unrivalled controller.

AVAILABLE AT:  
**GAME**

[eu.razerzone.com](http://eu.razerzone.com)

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# INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

CHRISTMAS 2016

EDITED BY RUSSELL DEEKS

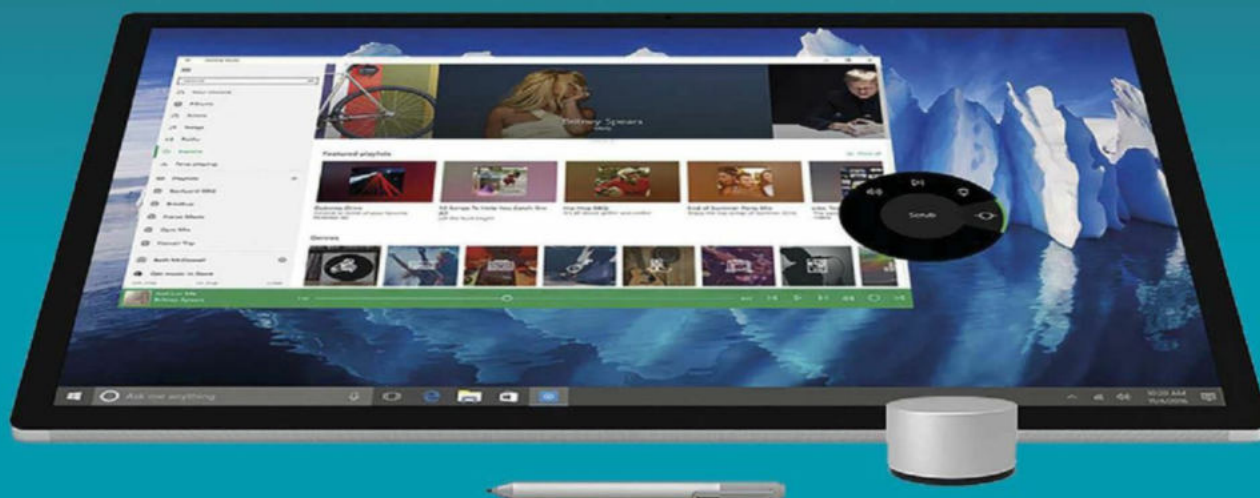


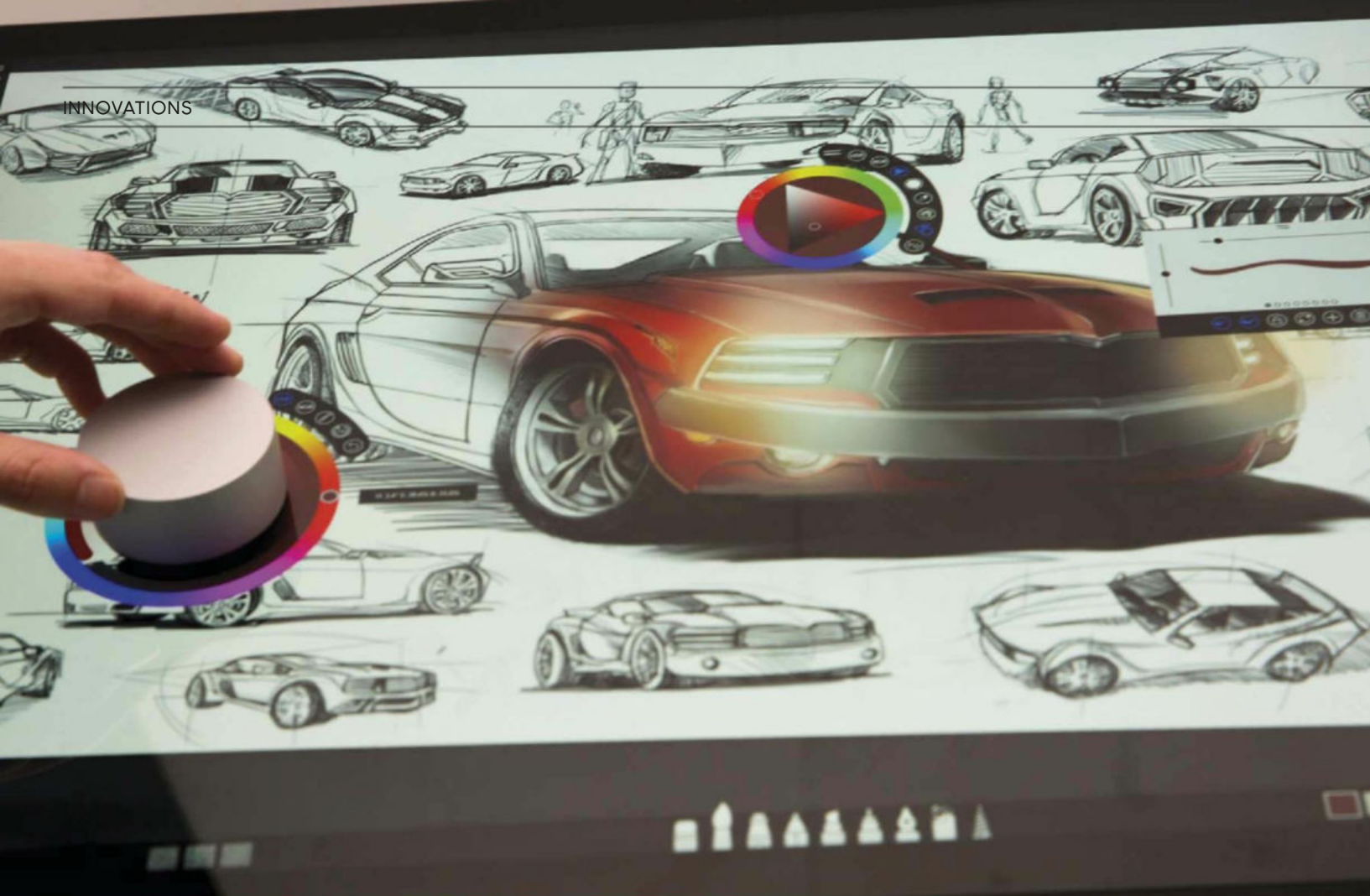
## APPLE VS MICROSOFT (AGAIN)

With new flagship machines just announced by both companies, the old rivalry is heating up

Both Apple and Microsoft have launched new flagship computers, in the form of the new MacBook Pro and the Surface Studio. While the two products aren't direct competitors, both sport a number of technological innovations that open up new fronts in the two companies' eternal battle.

In Apple's case, the headline news is the introduction of the new Touch Bar that runs along the top of the keyboard (though this is absent from the entry-level 13-inch model). This touch-sensitive OLED strip replaces the function keys with context-specific buttons and menus that appear depending what software you're using at the time. It's designed to





• eliminate the need to remember keyboard shortcuts, and will also show iOS-style Quick Typing suggestions. If you're attached to them, the existing function keys can be made to appear on the strip by pressing the Function key.

Other innovative features on the new MacBook Pro include a power button that doubles as a TouchID sensor, and a much larger trackpad. So far, so good – but there's a rather large 'but' coming.

True to its ongoing obsession with making everything slimmer and lighter, Apple has served up a new MacBook Pro that's almost devoid of ports. There's no MagSafe power port, no HDMI, no Display Port, no SD card slot and no USB – just two USB-C ports on the entry-level 13-inch model, and four on the 15-inch and higher-end 13-inch models.

The result is a machine that's slightly slimmer than its predecessor, but whatever weight you save is likely to be more than made up for by the number of dongles and adaptors you'll need to carry around – each of which also adds to the cost. £10 here or £20 there might not sound a lot, but given that even a midrange 13-inch MacBook Pro costs £1,749, while the top-of-the-range 2.7GHz 15-inch with a 512GB SSD costs a whopping £2,699, having to fork out extra

## EVEN A MIDRANGE 13-INCH MACBOOK PRO COSTS £1,749. HAVING TO FORK OUT EXTRA FOR A POCKETFUL OF DONGLES ADDS INSULT TO INJURY

for a pocketful of dongles does smack of adding insult to injury. We've heard many long-term Mac users – mostly music and design professionals, who've been Apple's core market forever – say they're now considering buying Windows machines for the first time in decades. But Apple's clearly hoping brand loyalty will keep its customers faithful.

### TOUCH DIALLING

Meanwhile over at Microsoft, all eyes are on the new Surface Touch desktop, and the accompanying Surface Dial.

The former is Microsoft's first all-in-one computer and is aimed at creative pros, with a 28-inch touchscreen display that can be tilted to just about any angle – even right back to 20°, at which

point you've essentially got a high-tech drawing board. It's a rival to Apple's 27-inch iMac, with the 'basic' model expected to cost £2,500+ when it goes on sale early next year, and offering a 1TB hybrid solid state/hard disk drive, 8GB of RAM and a 2GB i5 processor. You can have 32GB of RAM, a 2TB drive and an i7 CPU if you want them, but don't expect much change out of £4,000.

As for the Surface Dial, that's perhaps the most interesting new feature of all. The scroll wheel can be user-assigned to whatever software parameters you wish, whether that's adjusting colour levels in an image or simply scrolling through menu options. It costs an extra \$100 (£80 approx), but offers a new level of hands-on control that will appeal to certain types of users, such as music and video producers. Dial offers haptic feedback, and if held against the Touch's screen also brings up default options (such as a colour wheel) at the press of a button.

Tellingly, US buyers are being offered \$650 off the price of a Surface Touch if they trade in their old Mac laptop, which seems to confirm that Microsoft has its eyes firmly on Apple's core user base of creative professionals. As we said at the start, the old rivalry doesn't look like cooling any time soon...





## NETWORKS

## Rebuilding the Internet of Things

Internet of Things (IoT) devices are starting to sell in large numbers. But that increased uptake, it turns out, isn't entirely free of scaling problems.

For that reason, various technology companies are now working on improving IoT infrastructure. Intel, for instance, has introduced two new Atom processors, with the E3900 built specifically for wearables and other connected devices while the A3900 is aimed at automobile computers.

But new chips are small potatoes, if you'll pardon the pun, compared to building whole new mobile data networks, which is what the likes of Orange and Vodafone are doing. This is

because existing networks, which were built for carphones, rely on your phone contacting the nearest mast many times per second, which drains battery life.

The new networks use lower-power radio chips which contact towers only when necessary, meaning battery life is hugely improved. They'll also operate in previously unused areas of the wireless spectrum, and prioritise range over bandwidth (because with the IoT, you're typically not streaming HD movies, you're sending small chunks of data such as meter readings).

The result *should* be cheaper, more reliable IoT devices – but we'll reserve judgement until it happens.

## MATERIALS

## Your phone is killing gorillas

A Wildlife Conservation Society survey has found there are now just 3,800 eastern lowland gorillas left in the world. That's a big drop from the 16,900 that were counted 20 years ago – and it's mostly down to our addiction to smartphones and computers.

Such devices feature circuits built using the metal tantalum, which is extracted from the mineral coltan. The survey says it's coltan mining in the Democratic Republic of the Congo that is largely responsible for decimating the gorilla population. Not only are large chunks of their habitat being destroyed, but miners have developed a taste for gorilla meat in recent years.

Conservationists are now calling for a crackdown on illegal mining in the area, and for manufacturers to use minerals from less problematic sources.



## TRANSPORT

## On your bike!

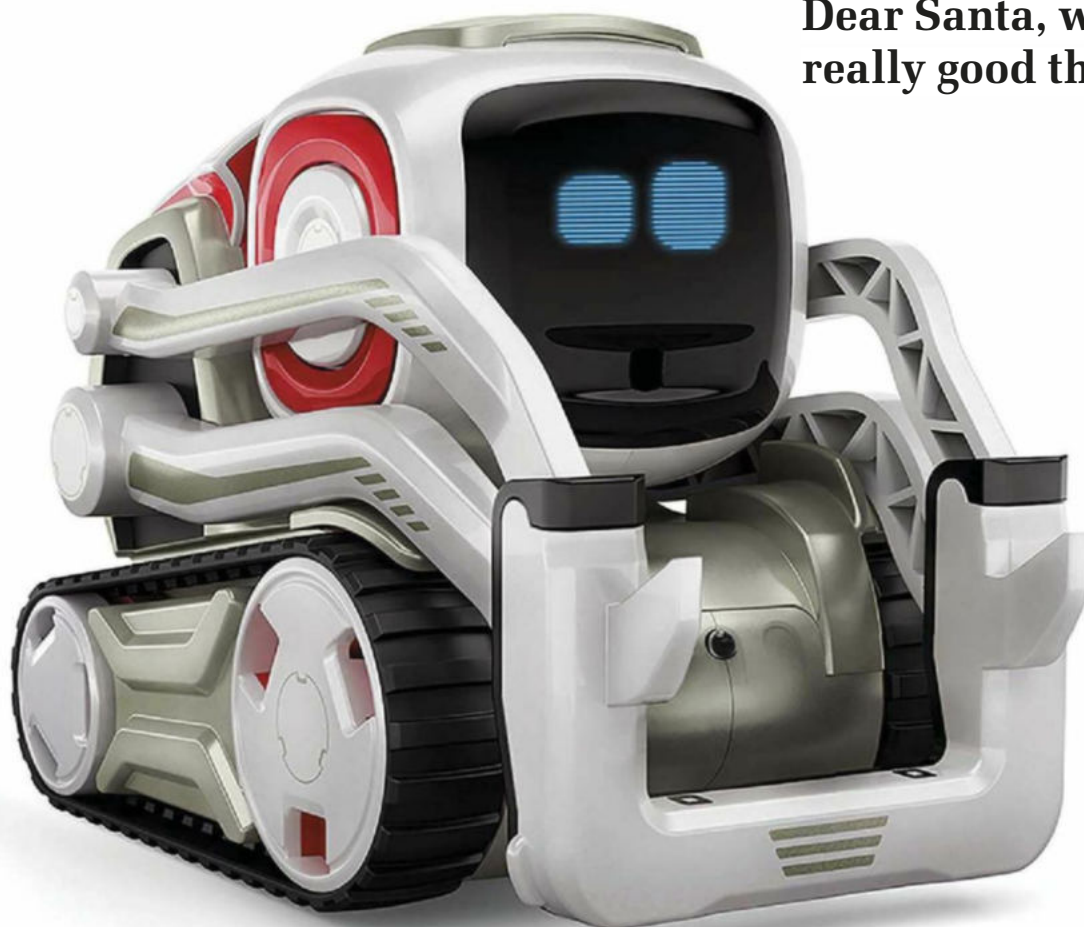
Croatia's Rimac Automobili has unveiled what is currently the world's longest-range electric bicycle. The Greyp G12H can go up to 240km (150 miles) on a single charge of its 3kWh battery – which will cost you a mere 29p, making the Greyp G12H one of the cheapest forms of powered transport there is.

Other than that super-efficient battery, the bike retains many of the same features as its predecessor, the Greyp G12S. Both feature a fingerprint-based biometric lock and built-in cycling computer, and both have a 'street mode' that limits you to 25km/h. This is to avoid being classed as a motorbike under EU law; the *actual* top speed of is 70km/h, because as their styling suggests, the bikes are really built for dirt track riding. There's no word yet as to price, but the G12S costs around £7,500, so with the added battery power, expect to pay a little more for the G12H.



# ALL WE WANT FOR CHRISTMAS

Dear Santa, we've been really, really good this year... honest!



## Buddy bot

**ANKI COZMO**

This tiny robot is controlled by an iOS/Android app, comes with light-up blocks for playing games, and has both an AI system that means it learns as it goes along, and an 'emotion engine' that gives it uncannily human-like responses to different stimuli. It *will* be love at first sight, trust us!

£180, [anki.com](http://anki.com)

## Digital PA system

**AMAZON ECHO**

Echo plugs into any 'smart' device, from cars to lights to your heating, and lets you control them with voice commands. It's great for playing music or searching the web, but do bear in mind that Alexa, the AI assistant inside Echo, will remember *everything* you ask. Forever.

£49.99/£149.99, [amazon.co.uk](http://amazon.co.uk)



## World shut your mouth

**SENNHEISER PCX550**

These wireless, noise-cancelling cans are eerily light and comfy considering how much tech is crammed in. As well as touch panels on the sides to control your music, there's a noise limiter to protect your ears.

£329.99, [sennheiser.com](http://sennheiser.com)



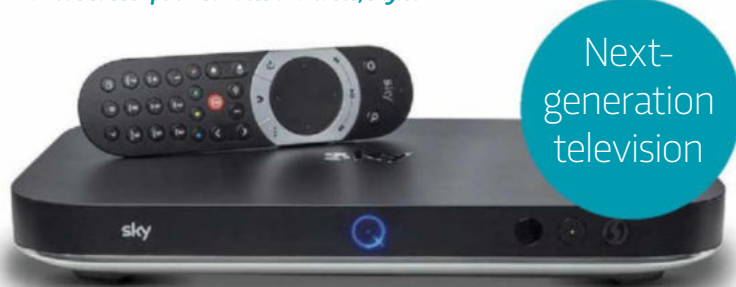


## Here's looking at Q

### SKY Q

With room-to-room streaming, endless boxsets, near-inexhaustible movie back catalogues and now 4K content, Sky's newest service has made us never want to look at another TV service again. Sorry, Netflix!

Various subscription bundles available, [sky.com](http://sky.com)



## Here be dragonflies

### DRAGONFLY DAC

Plug this DAC/preamp/headphone amp combi into a USB port and it'll bypass your computer's audio circuitry, feeding crisp, clean sound to your headphones or powered speakers. The Black and Red models will work with smartphones, too.

£89 (Original) or £169 (Black/Red), [audioquest.com](http://audioquest.com)



## High flyers

### STAR WARS DRONES

If you, like JJ Abrams, want to rehash your favourite *Star Wars* films, then these are definitely the drones you're looking for. Equipped with lasers, you can pit TIE Fighter against X-Wing until your heart explodes with nostalgia.

£239.99, [propelw.com](http://propelw.com)



# STOCKING FILLERS

Five great present ideas if you're on a tight budget

## Nintendo Classic Mini

Pick one up. Play *Super Mario Bros.* Turn it off in a blind rage two hours later when you remember how just brain-itchingly infuriating Mario and his eight-bit mates could be.

£50, [nintendo.co.uk](http://nintendo.co.uk)



## Gamer Fuel Mug

And for the gamer who's got everything? We heartily recommend this nostalgic mug with its joystick-style handle and retro text. It doesn't actually do anything – it's just a mug – but we totally want one anyway.

£9.99, [iwantoneofthose.com](http://iwantoneofthose.com)



## 3-in-1 Powerbank

Portable powerbanks, while undoubtedly useful, are ten-a-penny these days. This one, though, doubles as a torch (battery life: 50 hours) and a handwarmer (keeping your fingers toasty for 4-5 hours).

£17.99, [iwantoneofthose.com](http://iwantoneofthose.com)



## Cinema Light Box

Perfect for those *Star Wars* or *Godfather* marathons, this lightbox/lamp comes with 69 re-usable acetate letters and numbers, so you can display movie titles or whatever other message you see fit.

£29.99, [firebox.com](http://firebox.com)



## USB Mix Tape

A 1GB USB stick in a retro cassette-style box, so you can give the object of your desires a mix tape just like it was 1985 all over again. Judging by the office reaction, will work better as a gift for those who actually remember what a C90 was!

£12.99, [iwantoneofthose.com](http://iwantoneofthose.com)





Make  
music on  
the move

## Block party

### ROLI BLOCKS

Make music easily with BLOCKS. The starter Lightpad Block is a hardware controller for Roli's iOS app NOISE, presenting you with a grid of coloured squares that you tap or swipe to generate sounds you've assigned to them. The Live Block adds expression 'pedals', while the Loop Block has transport and tempo controls.

From £169.95, [roli.com](http://roli.com)

## Pocket prints

### HP SPROCKET

Want to print out your smartphone snaps? HP's pocket-sized printer produces adhesive-backed, 5x7.6cm pictures on Zink photo paper that you can customise with borders and text. It'll print your Facebook, Flickr and Instagram pics, too.

£129, [hp.com](http://hp.com)



## Daydream believer

### GOOGLE DAYDREAM

Google's new VR headset is a big step up from Cardboard. In place of fold-it-yourself goggles you get a visor with a hard fabric-bound body and soft elasticated strap, plus a handheld remote so you can play games as well as watching VR movie clips.

£69, [vr.google.com](http://vr.google.com)

## Go Pro!

### PLAYSTATION PRO

With a heap of new tech inside, the PS Pro is halfway to a new console. New graphics tricks will be able to make new games look better and upscale some old ones to run them at 4K resolution.

£349, [playstation.com](http://playstation.com)



## Stick 'em up

### INTEL COMPUTE STICK

The Compute Stick is another thumb drive-sized device, but this one packs a quad-core Intel Atom processor, up to 4GB of RAM and 64GB of internal storage. Plug it into any HDMI display, add a wireless keyboard/mouse, and you've got a fully-fledged PC.

£117-£360, [intel.com](http://intel.com)





## The Doppler effect

### DOPPLER LABS HERE ONE

These wireless earbuds feature a smart, user-adjustable noise reduction system that lets you control (using an iOS/Android app) just how much of the outside world you can hear – right down to filtering out specific frequencies – making crying babies on planes suddenly a lot less of a problem.

£259.99, [hereplus.me](http://hereplus.me)

## Room mate

### LITTLE BITS RULE YOUR ROOM KIT

This DIY room security system is the latest in a long line of electronic building sets from Little Bits. From a basic synthesizer to an IoT device only you've ever thought of, the possibilities are almost endless.

£99 (£80 approx), [littlebits.cc](http://littlebits.cc)



## IF MONEY'S NO OBJECT

You'd better start being nice to well-heeled relatives...

### Dyson 360 Eye

Pretty much the *only* vacuum that makes an acceptable Christmas present! Armed with caterpillar treads, a 360° camera and machine-learning algorithms, it'll make light work of the post-Xmas clean up.

£799, [dyson.co.uk](http://dyson.co.uk)



### LG G6V OLED TV

No thicker than a 50p coin, this OLED panel screen needs no backlight, and so offers one of the most cinematic experiences we've ever enjoyed on a TV. At £6K, though, you'll need to have been very, very good this year...

£5,999, [lg.com](http://lg.com)



### DJI Mavic Pro

This compact, foldable drone will fit into a backpack and travel with you. Anti-collision sensors will stop you crashing it, and it will even fly itself, following you as it goes. But we'd *still* probably manage to break it somehow...

£999, [dji.com](http://dji.com)



### Devialet Phantom

No, not a ghost who issues driving licences (DVLA...) but a very stylish wireless speaker that pumps out 750W of sound. Add extra Phantoms and they'll sync automatically for hassle-free multi-room audio.

£1,690, [devialet.com](http://devialet.com)



### Sony Alpha A99 II

Sony has finally brought out a DSLR that can also shoot 4K video. Throw in a 42.4MP sensor, max ISO of 102,400 and a 1,024x768 OLED viewfinder, and you're looking at a serious camera at a serious price.

£3,000, [sony.co.uk](http://sony.co.uk)



# REPLY

Your opinions on science, technology and *BBC Focus*

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## MESSAGE OF THE MONTH

### Unnecessary cruelty

I really enjoy reading *Focus* magazine. It has opened my mind so much to nature and science, and I find I want to learn more, especially as more things seem to be being discovered.

It makes me sad, though, that in this quest for knowledge, scientists feel the need to experiment on animals. The article on page 23 of your November issue, describing experiments on rhesus macaques, particularly upset me. The cruelty that is being inflicted on these amazing animals is heartbreaking.

In our quest to find out more about this fantastic planet, we should bear in mind that we share it with other creatures which we need to respect and care for, not exploit. We need to care at the same time as we explore – it's what makes us human.

Mrs Vivienne Prendergast, Coventry

➔ I suspect that many researchers, even those that run experiments on animals, would agree with you on this matter. However, a lot of scientists maintain that there are not enough satisfactory alternatives to animal testing for it to be completely abolished. In the UK, scientists have to adhere to strict welfare practices, and non-animal procedures will be used where possible. Don't forget that animal tests have helped us to develop antibiotics, chemotherapy and transplants, to name a few.

Personally, we hope that advances like 3D printed tissues and organs will mean that we won't have to continue testing on animals for too much longer. – **Ed**

#### WRITE IN AND WIN!

The writer of next issue's *Message Of The Month* wins a **Sheaffer 100 pen set**, worth £40. The ballpoint and fountain pen, in Sheaffer's newest Pure White colour option, feature laser-cut bodies and a lacquer finish, and come in their own stylish presentation box. [sheaffer.com](http://sheaffer.com)

WORTH  
£40



Are animal experiments necessary?  
Vivienne Prendergast doesn't think so

#### Moths to a flame

Regarding the feature 'Is technology changing our brains?', I fear the rise of the screens is creating a distance between our nervous system involving our tactile interaction with the real world. Mobile devices are addictive and people find it hard to leave theirs alone even when they're not looking at them, maybe because the body craves something real to hold onto.

Future generations of children could find it hard to relate to the real world in the same tactile, three-dimensional way that their parents have in the

past. For instance, e-readers lack many subtle tactile components such as feeling and smelling the pages, hearing the sound of the paper, feeling the weight and dimensions of the book etc. This can also be seen in everything that has been reduced to software.

It's hard to think of any other species that is becoming so bereft of the sensory experience of life, and becoming so addicted – with the exception, perhaps, of moths being drawn to a flame!

Anthony Hammond, via email

#### Age concern

Having just turned 50, the view held by Aubrey de Grey that the first person to reach 1,000 years of age is already alive ('The ten strangest ideas', December, p60) intrigues me. But I fear it is also, alas, cobbler's. Doubly so if the person could have been aged 50-60 in 2008 when de Grey seems first to have made the claim. If progress has been slow since then, and there are still no

easy wins to be had, it would seem time is rapidly running out for this particular person.

I'll applaud anyone doing useful research into anything which improves the human condition. There's no doubt that ageing (and the problems it brings) will be the first world's biggest health problem in coming decades. But I fear de Grey's mistake is believing that if you understand a problem, then a solution must be within reach.



Is an end to ageing in sight? Possibly not...



The two words I would urge anyone making this mistake to remember are 'nuclear' and 'fusion', in that while I have no doubt we'll crack it eventually, understanding and practical results can remain frustratingly hard to unite.

It might have been better, if paucity of funding is the main problem, to have claimed that a life expectancy of 200 was possible rather than 1,000. That might have felt plausible enough to attract the big bucks – money that would be well-spent if he were right.

Simon Bartlett, via email

### How green is your energy?

In answer to the Q&A question 'What is the greenest energy source?' (December, p108), you suggest that hydropower, with the lowest carbon footprint, may be the winner. I tend to agree, though suggest that where hydropower dams have been built in the UK they have *not* disrupted rivers' ecosystems to any noticeable degree.

However, I was unhappy that you omitted to mention nuclear power schemes as contenders for the greenest energy source. The reports I have seen put nuclear a very close second to hydropower in terms of

environmental impact, and with much greater generating capacity over hydropower, nuclear should probably be Number One.

However, I am happy with any source of energy provided it doesn't cause excessive global warming, is sustainable and can be supplied to the consumer at an affordable price.  
C Scott, Edinburgh

### Problem solved?

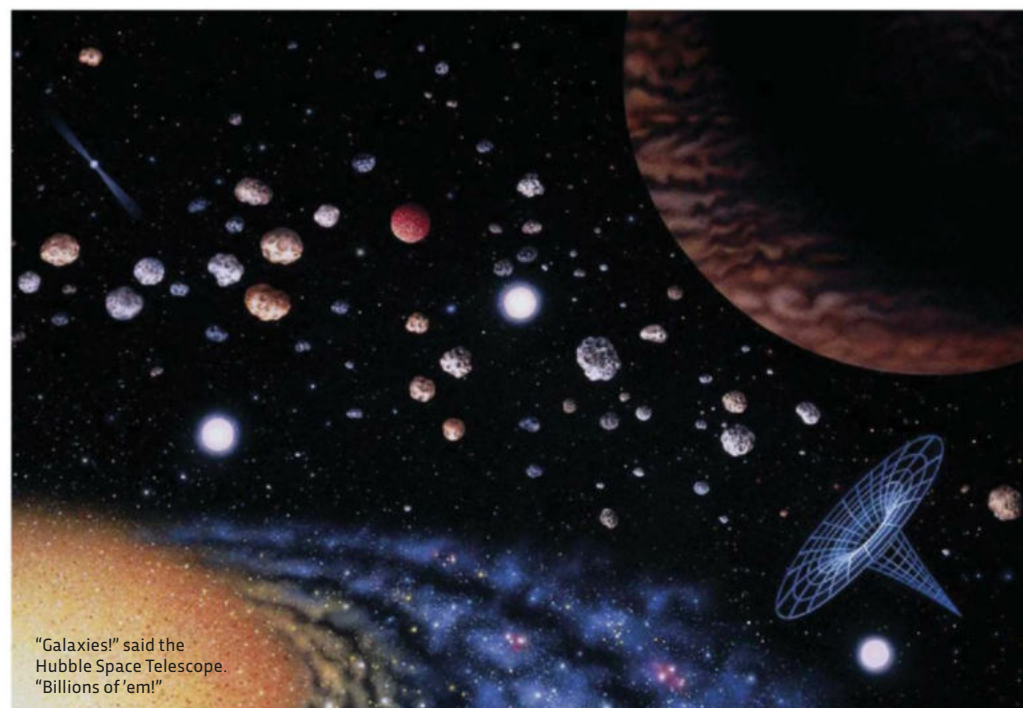
On page 15 of your December issue, I read that there are now thought to be an estimated two trillion galaxies in the observable Universe; 10 times the number that were previously believed to exist.

Scientists are searching for dark matter because calculations show there isn't enough matter in the Universe to explain certain theories. – we're told that 90 per cent of it appears to be 'missing'. But in light of the Hubble observations, is the search for dark matter still valid?

Michael Weaver, Weston-Super-Mare

➔ It is. Although the numbers here appear to offer an 'easy' answer, dark matter can't simply be the ordinary stuff that makes up galaxies, as it would lead to the wrong mix of elements emerging from the Big Bang.

– Robert Matthews, science consultant



"Galaxies!" said the Hubble Space Telescope.  
"Billions of 'em!"

## MORE FOCUS FOR YOU

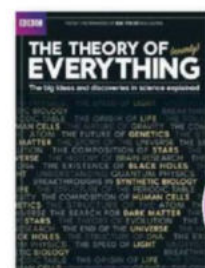
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# THE FINAL FRONTIER

We know more about outer space than our own oceans; we have better maps of Mars and Venus than the seabed. So meet a new breed of divers who are boldly going where no scientist has gone before...

Words: Dr Helen Scales









**U**ntil about a century ago, it was thought that not much lived in the deep sea. With its average depth of around 3.5km, crushing pressures and permanent darkness, few people bothered looking there – what could hope to survive in such an environment?

According to the US National Oceanic and Atmospheric Administration (NOAA), 95 per cent of the oceans are still completely unexplored. But today's scientists have ditched the old ideas of a deep, empty ocean and flat, featureless seabed. They're keen to take a closer look beneath the waves, and the latest generation of research equipment is opening up the depths like never before. New technology is helping scientists uncover the oceans' vital role in global climate, and find bizarre creatures that offer clues about the origins of life on Earth – and the possibility of life in outer space.

"It feels like I'm  
somewhere  
I shouldn't be.  
This kind of  
exploration can  
give you tingles"



## DEEPER DIVING

### Exploring the mysterious 'twilight zone'

"It feels like I'm somewhere I shouldn't be," says Jack Laverick, a PhD student at Oxford University, as he recalls being the first person to see part of a 100m-deep Caribbean reef. "This kind of exploration can give you tingles."

He's one of a new breed of scientists who are venturing deeper than most scuba divers ever go. Divers can now descend into the 'twilight zone', from 50m down, where sunlight begins to run out. Few have visited these depths, but now rebreathers are making it possible.

Although invented before scuba equipment, rebreathers have only recently become safe enough for use in research. Instead of bubbling exhaled air into the water they recycle it, scrubbing out carbon dioxide and topping up the

breathable oxygen. Astronauts on space walks use similar apparatus.

Dominic Andradi-Brown, another deep-diving PhD student from Oxford, recounts the excitement of descending the sheer face of an underwater cliff. "It feels like you're going off the edge of an abyss and anything could be below you."

Laverick and Andradi-Brown took part in Thinking Deep, a 2015 dive off the island of Utila in Honduras. Using rebreathers, they dived into the twilight zone for up to four hours at a time. This let them access parts of the oceans that are understudied. Submersibles go much deeper than this, while regular scuba divers can't safely go beyond 40m. "There's this really understudied middle bit," explains Laverick.





PHOTOS: OCEAN RESEARCH AND CONSERVATION GROUP/UNIVERSITY OF OXFORD, JOACHIM PLOETZ/ALFRED WENEGER INSTITUTE

Less than a decade ago, researchers confirmed that tropical coral reefs grow into the twilight zone – despite corals usually being associated with the sunny conditions in shallow waters. These ‘mesophotic reefs’ could provide species a refuge from threats that impact shallower waters, such as overfishing and rising sea temperatures. Laverick is investigating whether shallow, damaged reefs could regrow from young corals born in the deep.

Andradi-Brown, meanwhile, is studying fish. Below 60m, he’s seen shark species that have been all but wiped out by fishing closer to the surface. “Coral reefs are a doom and gloom story at the moment,” he says, “but these deep refuges are showing real potential.”

# CALL IN THE SEALS

How sensor-equipped seals are helping scientists peer below the Antarctic ice

Tagging huge elephant seals on an Antarctic beach isn’t a job for the faint-hearted. Mature males weigh up to four tonnes, and can easily mistake a human for another seal looking for a fight. “Elephant seals don’t have good vision,” says Dr Horst Bornemann, a researcher from Germany’s Alfred Wegener Institute for Polar and Marine Research. “You want a team who can anticipate their behaviour and fend off advancing territorial males.”

There’s a good reason for working with such colossal, bad-tempered animals in remote, sub-zero conditions, though. Southern elephant seals, the deepest-diving seal species, can dive below 2,000m for hours at time, so fixing small, electronic sensors to their heads can transform them into a fleet of researchers. These sensors gather data on the seals’ movements – how deep they dive, what they eat and where they go – and can ping information back up to 250 times a day, when the seal surfaces for air.

Tagged seals can help answer important questions about the oceans. Over seven years, close to 20,000 dives were logged by dozens of elephant and crabeater seals in parts of the Bellingshausen Sea, off the Antarctic Peninsula, where research vessels rarely venture. Another recent study used information from a programme called MEOP – Marine Mammals Exploring the Oceans Pole-to-Pole – to understand more about why West Antarctic ice shelves are melting, showing that a layer of warm, salty water is edging up to the continental shelves surrounding Antarctica.

“There are ice-covered areas, in which it’s a huge effort to manoeuvre a ship,” says Bornemann. “But seals can cope with any icy conditions, all year round. So you get perfect winter data.”



Attaching sensors to four-tonne elephant seals can be dangerous



# ROBOT SUBS

How gliders are going where humans can't

"Very small, gentle submarines." That's how oceanographer Dr Pierre Testor from Paris's Pierre And Marie Curie University describes the underwater robots he works with. In the 1980s, scientists came up with the idea of long-range vehicles that could explore hard-to-reach areas of the oceans. Today, fleets of autonomous robots known as gliders scour the seas for months at a time, gathering crucial data about how the oceans work.

When Testor starting carrying out his glider studies a decade ago, the worry of not knowing if costly equipment would make it back in one piece was tempered by the excitement of new discoveries. "I felt I was starting to do oceanography in a different way," he recalls. Since then he's seen gliders used in all spheres of ocean science, from physics to biology.

Current gliders can reach depths of 1,000m, but Testor is deputy science coordinator of a European project, BRIDGES, which is developing new

gliders that go much deeper. "We plan to produce a glider that's able to go to really great depths, around 6,000m," he says. This means they'll be able to reach around 98 per cent of the oceans. A big part of the gliders' success is their extreme efficiency: they consume about the same amount of power as two Christmas tree lights.

The new BRIDGES gliders are intended for academic and industrial uses, including monitoring pollution from deep-sea mines. Rare earth minerals are in huge demand from the electronics industry and could soon be extracted from the seabed and oceanic hydrothermal vents. Conservationists are concerned that such mines will be very difficult to monitor. It's therefore hoped gliders will help keep an eye on operations many kilometres beneath the waves: equipped with acoustic sensors, they'll be able to detect clouds of metal-rich sediments churned up by the mines.

BELOW: A depth chart of part of the Gulf of Lyon in the Mediterranean, produced using one of BRIDGES' gliders



# THE MOST MYSTERIOUS PLACES IN THE OCEANS

## THE CASCADIA MARGIN

The Ocean Exploration Trust recently found 500 spots off the US west coast where methane bubbles out of the seabed like champagne, and where several little-known species thrive.



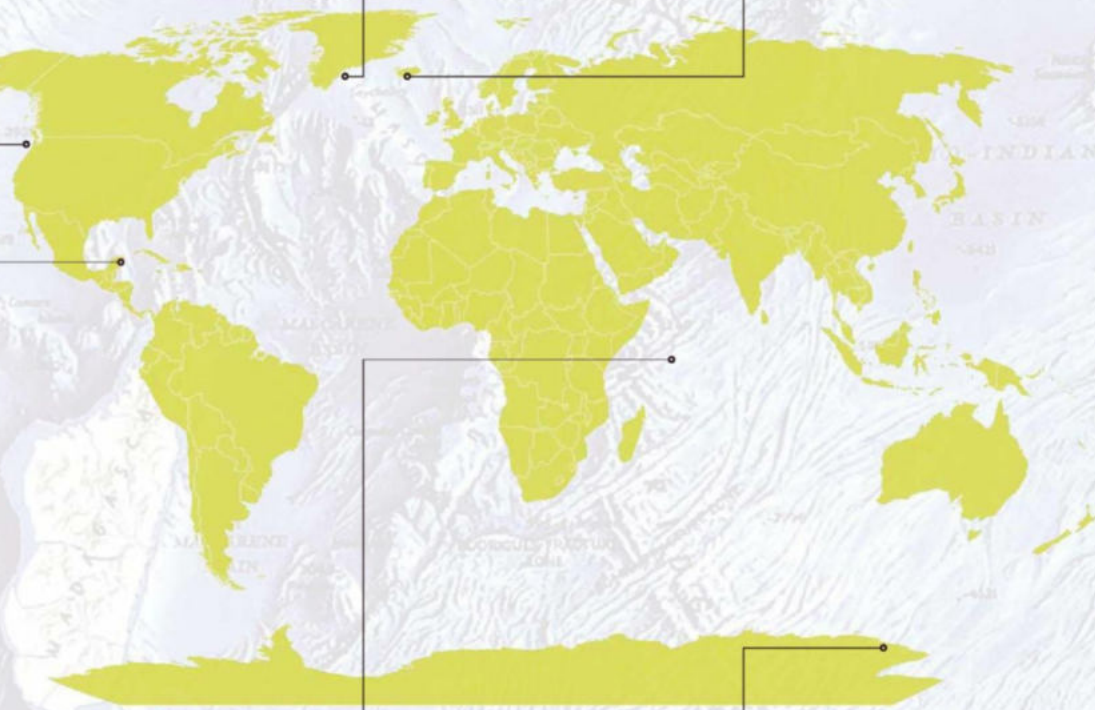
## GREENLAND

In 2012, researchers stumbled across a coral reef while taking water samples 900m down off Greenland's southern coast. Little is known about it, but similar reefs in Norway are 8,000 years old.



## SILFRA FISSURE

In the middle of Iceland, this is the only place where you can swim in the crack between two continents (the Eurasian and North American plates). It gets 2cm wider every year.



## YUCATÁN PENINSULA

Thousands of deep sinkholes form part of the longest underwater cave system in the world. The caves are flooded with freshwater overlying saltwater, and many remain unexplored.



## THE CHAGOS ISLANDS

Few coral reefs have been studied deeper than 40m, but in the Indian Ocean, healthy deep reefs in the Chagos Islands could help shallower areas recover from 2016's mass coral bleaching.



## THE ROSS ICE SHELF

Researchers drilling hundreds of metres through the world's largest ice shelf have found fish and crustacean species living underneath. How they got there – and survive – is a mystery.

PHOTOS: BRIDGES X2, GETTY X2, ALAMY, NASA, BEDFORD INSTITUTE OF OCEANOGRAPHY









## LITTLE MERMAID

### Building a distinctly human-like underwater avatar

Measuring 1.5m in length and weighing 180kg, OceanOne is quite unusual for a remotely operated underwater vehicle. Described as a 'robo-mermaid', it has a head, two cameras for 'eyes' and a pair of fully articulated arms, complete with wrists and fingers. OceanOne acts as an underwater avatar, allowing people to feel like they're diving to inaccessible depths while remaining safe and dry. A human pilot can see what the robot sees via stereoscopic cameras, and feel what it's holding via sensors in the robot's hands that transmit haptic feedback to a controller on the surface.

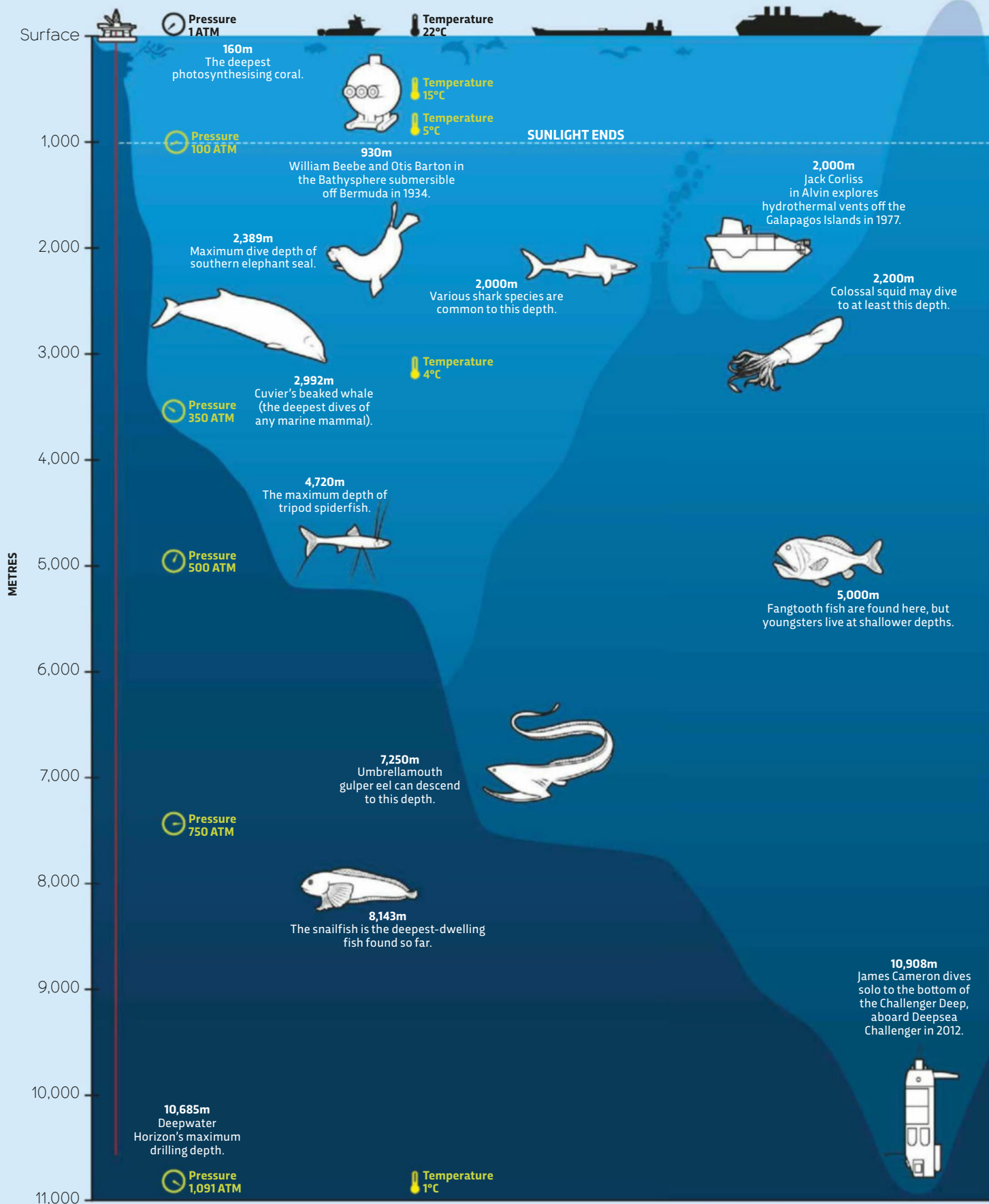
To a certain extent, OceanOne can even think for itself. Onboard processors analyse camera footage and adjust the thrusters in the

robot's tail to make sure it doesn't bump into anything. If sensors detect an unavoidable upcoming collision, the robot braces its arms to cushion the impact.

Built by a team at Stanford University, OceanOne's first mission, in April 2016, was to explore a 17th-Century shipwreck, *La Lune*, lying 100m deep in the Mediterranean. The humanoid robot carefully swam around the structure and gathered ancient artefacts without crushing them between its fingers.

The idea is that eventually the robo-mermaid will be able to perform other skilled tasks, such as examining fragile coral on reefs or operating machinery in places such as deep-sea mines and oil rigs.

## WHAT LIES BENEATH





# GOING DOWN, DOWN, DOWN ...

How next-generation submersibles are enabling scientists to dive deeper than ever before

“It’s as close to being in space as you can be on the Earth,” says Oxford University’s Prof Alex Rogers, as he recalls his journey to a depth of 3,380m inside the Japanese submersible Shinkai 6500. “You are so remote from your normal environment. There’s a real sense of isolation.”

Rogers is science director of a new deep-ocean research initiative called Nekton. On the first Nekton expedition in 2016, he explored the deep sea around Bermuda inside a Triton submersible. This two-person, three-tonne sub is relatively small and lightweight compared to many other submersibles, and highly manoeuvrable. It also has a huge acrylic dome, giving scientists fantastic views of the ocean for observation and research. “The submersibles are absolutely fantastic. It’s very James Bond,” says Rogers.

Among the things that Rogers and the Nekton team observed were huge forests of tree-like black corals stretching down to Triton’s depth limit of 300m. Giant sea fans and enormous sponges add to the strange, living seascape. To reach

deeper, the team will send down remotely operated vehicles and other deep water probes.

The long-term aim for Nekton is to document the life at depths between 200m and 3,000m in 14 distinct regions worldwide. These 14 regions are defined by particular attributes of the oceans, including temperature, salinity and currents. The team will also measure the health of these deep ecosystems and look for signs of human impacts, like trawling and plastic waste. Who knows what else could be lurking there?

Nekton uses two Triton subs, which gave Rogers a new perspective on the scale of the oceans. “You look across and see the other sub in the distance as this tiny, toy-like thing,” he says. “There are many scenes that are lodged in my memory. These majestic cliffs and landscapes... it can make you feel quite small.”



**Dr Helen Scales** (@helenscales) is a marine biologist, writer and broadcaster. Her latest book is *Spirals In Time: The Secret Life And Curious Afterlife Of Seashells* (£16.99, Bloomsbury Sigma).

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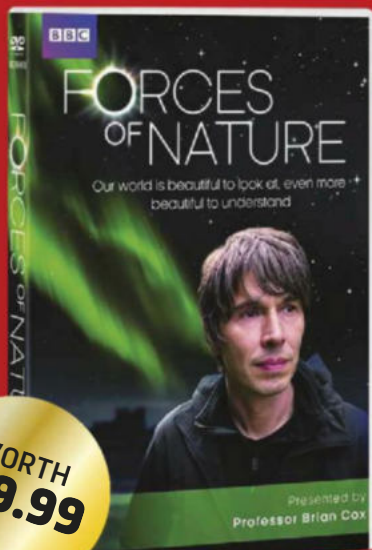
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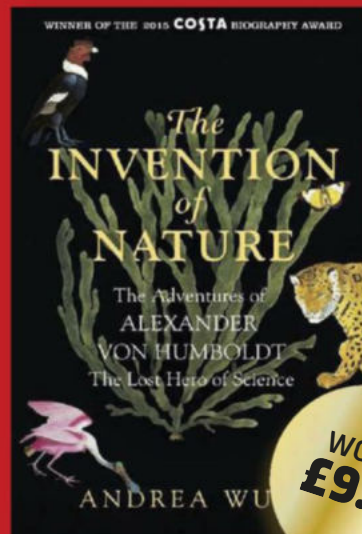
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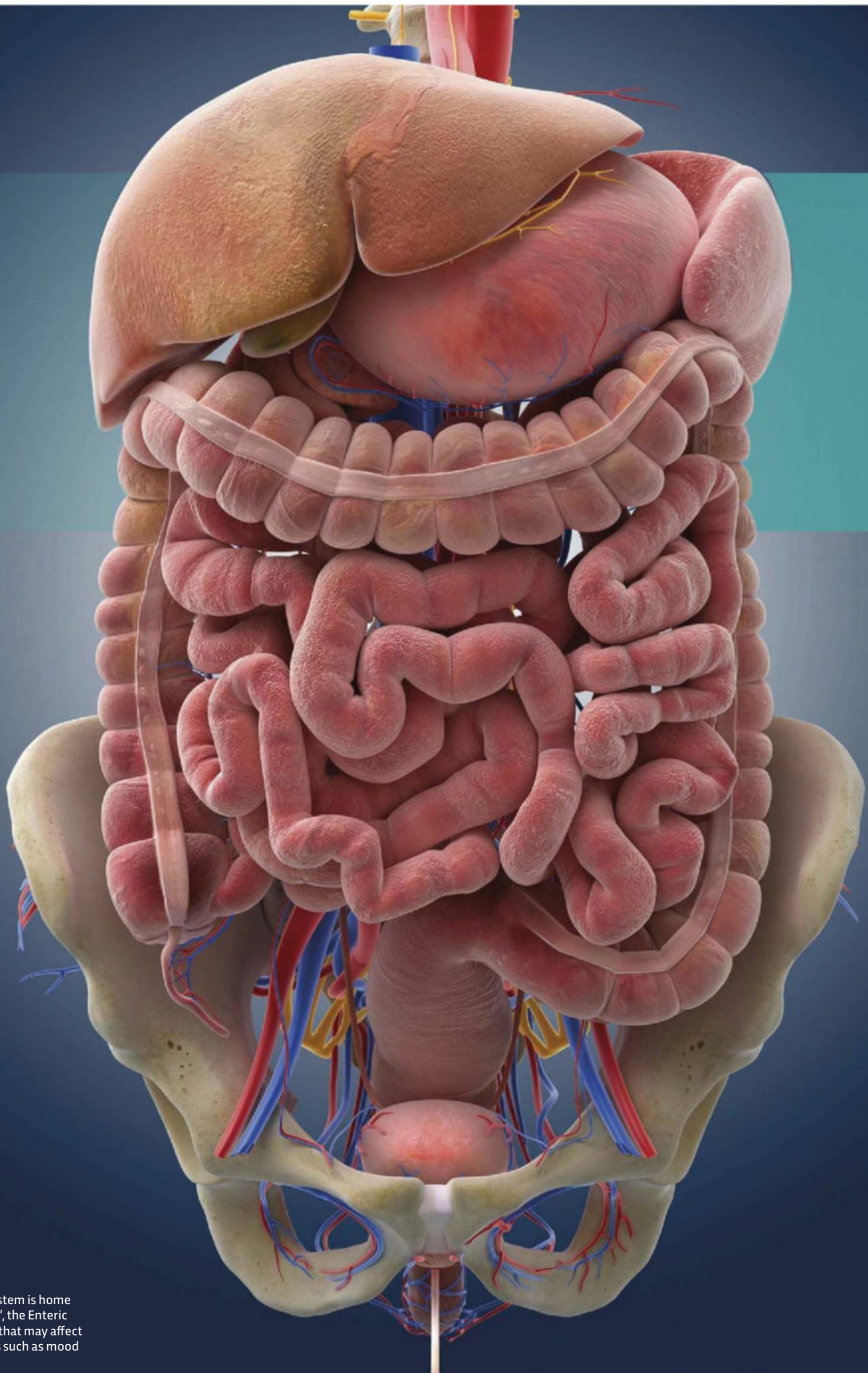
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Your digestive system is home to a 'second brain', the Enteric Nervous System, that may affect mental processes such as mood



# MEET YOUR SECOND BRAIN

Decision-making, mood, disease... scientists are discovering that the network of neurons in our gut is involved in a lot more than just digestion

WORDS: ROBERT MATTHEWS



You're facing a big decision – whether that's to go into a business partnership with a friend, say, or put money into a promising new idea. It's a tough call, as there are very few hard facts to go on. So it's time to use your second brain. Don't worry, you've probably used your second brain countless times before; it's just that when you did, you more likely referred to it as 'gut instinct'.

New research is showing that this age-old phrase is surprisingly accurate. We really *do* have a second brain that influences our judgment, and much else besides. Known as the Enteric Nervous System (ENS) – enteric meaning 'to do with intestines' – it's an extensive network of brain-like neurons and neurotransmitters wrapped in and around our gut.

Most of the time, we're unaware of its existence, as its prime function is what one would expect: managing digestion. Yet the presence of all that brain-like complexity is no coincidence. The ENS ►

It is in constant communication with the brain in our skull via the body's own information superhighway – the vagus nerve. And it's now becoming clear that all those signals flowing back and forth can influence our decisions, mood and general well-being.

"Your gut has capabilities that surpass all your other organs, and even rival your brain," says ENS specialist Dr Emeran Mayer of the University of California, Los Angeles, who is author of a new account of the science of the ENS, *The Mind-Gut Connection*. "This second brain is made up of 50-100 million nerve cells, as many as are contained in your spinal cord."

BELOW: The Enteric Nervous System (ENS) centres on the vagus nerve and the digestive tract

BELOW RIGHT: Stimulating the vagus nerve externally via an ear clip can help with depression

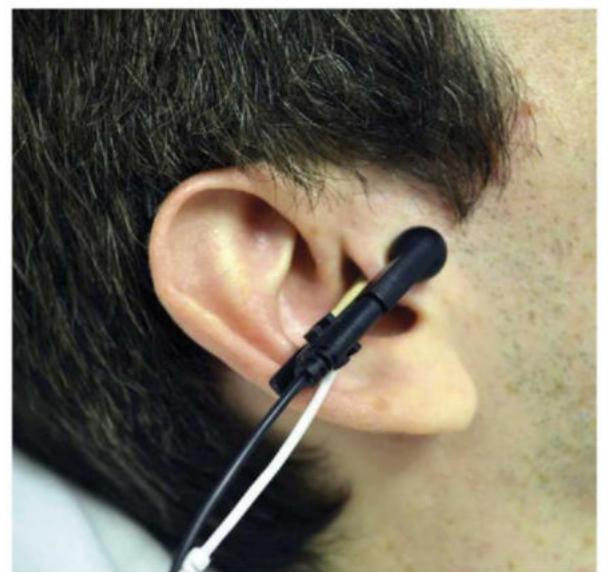
Researchers worldwide are now racing to explore the implications. The results are revealing the key role of the ENS in everyday health – and also what happens when it malfunctions. Links are emerging between the ENS and a host of disorders ranging from obesity and clinical depression to rheumatoid arthritis and even Parkinson's disease.

That, in turn, is opening up new approaches to treating these conditions, with some quite promising results already appearing.

## GLORIOUS GUTS

The ENS and the brain-gut connection look set to become a major focus for 21st-Century medicine. Yet the first hints of its importance actually emerged over a century ago, when researchers began making some strange discoveries about our digestive system.

Experiments by British doctors on animal organs revealed that the stomach and intestines have the bizarre ability to work autonomously, processing food even after they've been removed from the rest of the body. The ENS, it seemed, was clearly far more sophisticated than just a bag of nerves surrounding various organs, though the reason for its complexity was far from clear. Then in the 1980s, researchers made another startling discovery: the ENS is awash with neurotransmitters, the biochemicals that are vital to brain activity. By the late 1990s, researchers began talking of the ENS as the body's second brain. That led to some misconceptions, says Mayer: "There was a lot of hype around the idea that the ENS may be the seat of our unconscious mind".





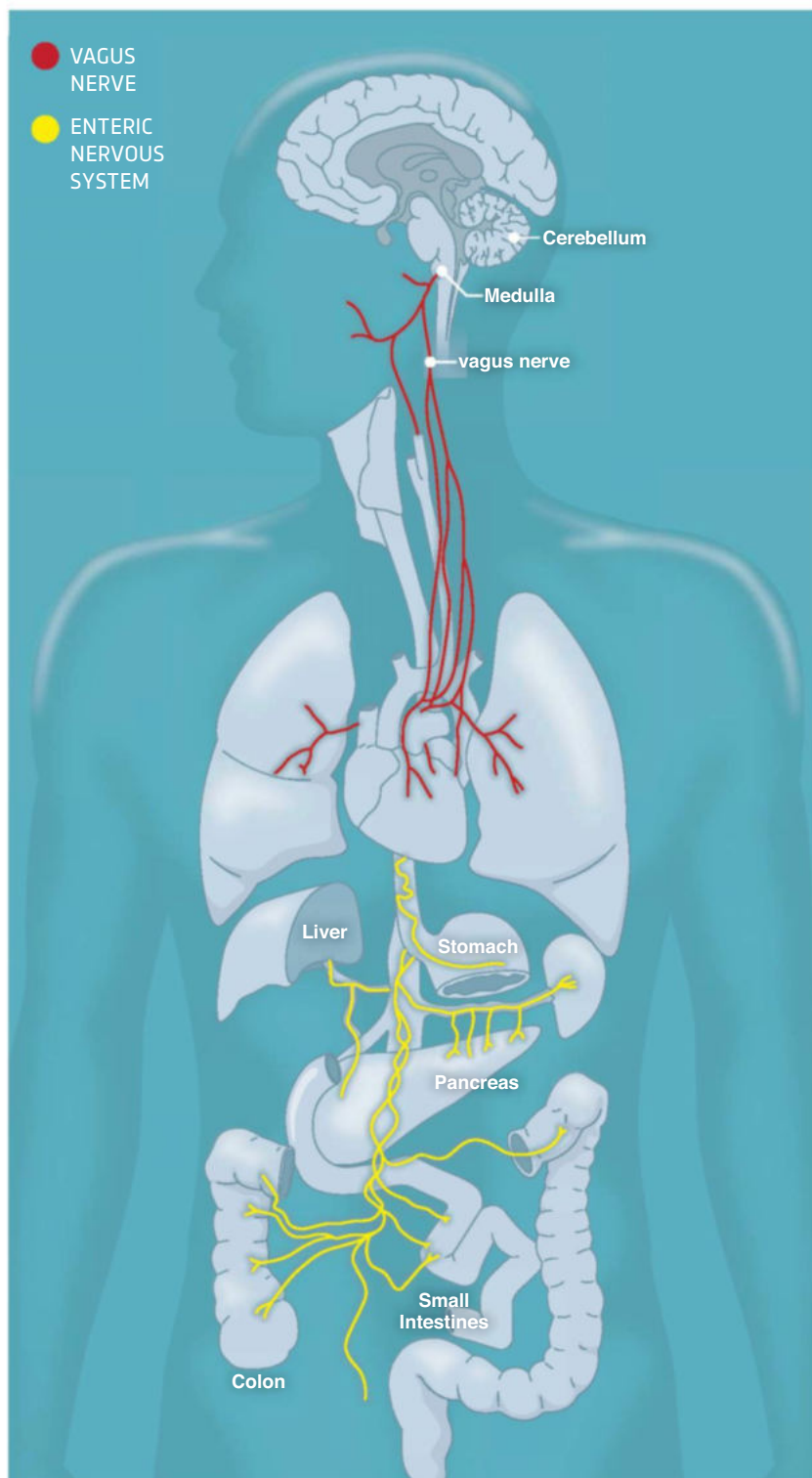
The reality is more nuanced and involves another of the key targets of current medical research: the microbiome (see the cover feature of *BBC Focus*, March 2015). This vast array of bacteria, viruses and other organisms is found throughout the body, but the biggest and most diverse collection is in the gut.

Like the ENS, these microbes are principally focused on the complex business of dealing with digestion. But their behaviour in the gut is constantly monitored by the ENS, and the information is relayed via the vagus nerve straight to the brain.

A clue to the key role the state of our gut plays in our well-being comes from the fact that around 80 per cent of the vagus nerve is dedicated to reporting information to the brain. Suddenly, the idea of having a 'gut instinct' no longer seems so ridiculous. We've all experienced sensations like queasiness and butterflies when faced with challenges, or felt 'sick to the stomach' when things don't go well. According to Mayer, the brain labels memories of such situations with the effect they had on our gut. The result is a rapid-access library that helps assess new challenges based – literally – on gut feeling rather than conscious, rational thought.

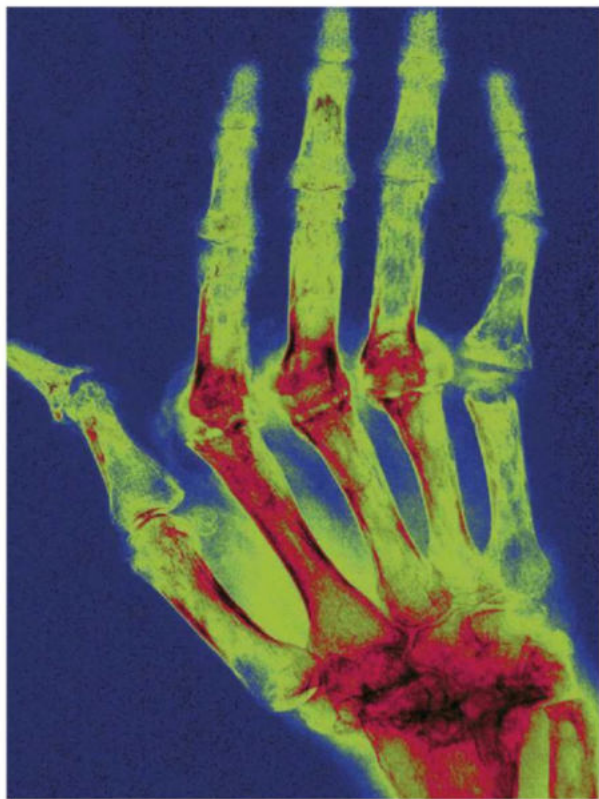
That's not to say you should always go with your gut. "The quality, accuracy and underlying biases of this gut-brain dialogue vary between different individuals," says Mayer. While fast, its response can also be warped by other life events or even what you ate. And sometimes it's just plain wrong. Faced with a huge financial decision, cool-headed analysis is a better bet than a snap gut decision. 🍷

**AROUND 80 PER CENT OF THE VAGUS NERVE IS DEDICATED TO REPORTING INFORMATION TO THE BRAIN. SUDDENLY, THE IDEA OF HAVING A 'GUT INSTINCT' NO LONGER SEEMS SO RIDICULOUS**



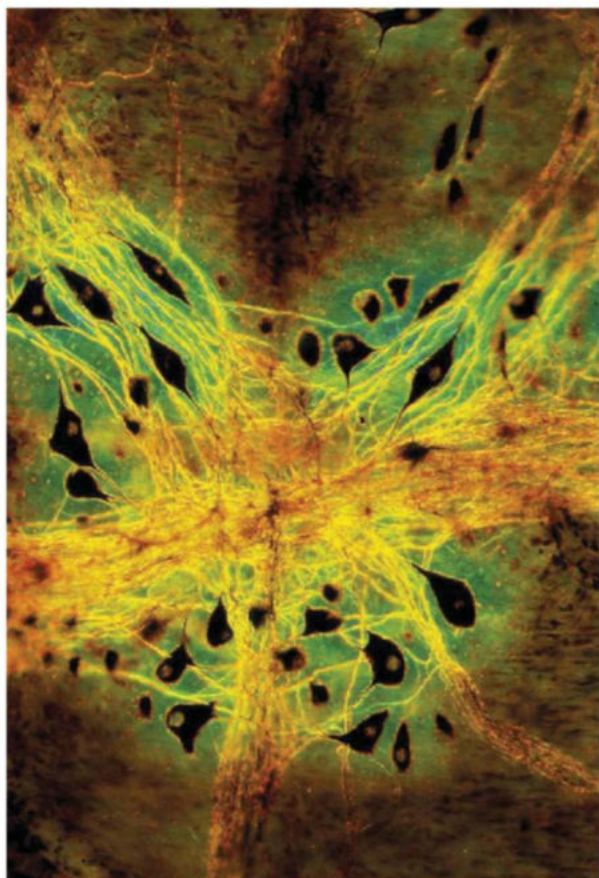
## THE BRAIN YOU NEVER KNEW YOU HAD

If you thought the only brain in your body is in your head, think again. Your grey matter is in constant communication with a vast network of neurons and neurotransmitters in your gut making up the so-called Enteric Nervous System (ENS). And the two are linked by an information superhighway known as the vagus nerve, which runs down each side of your neck and into your chest, branching out across your entire gut.



LEFT: Better knowledge of the ENS could help us treat conditions such as arthritis (pictured)

BELOW LEFT: The intestinal muscles are full of nerve cell bodies (black) and their axons and dendrites (yellow and orange)



## ● ELECTRIC FEEL

It's becoming increasingly clear that the ENS influences our brain at deeper, more subtle levels as well. Evidence is emerging that the ENS influences our mood, and even plays a role in depression. Exactly *how* it does this is still unclear, but researchers are currently focusing their efforts on one of the many neurotransmitters that are found in the ENS: serotonin.

Imbalances in serotonin have been implicated in depression for a long time, which is why it is the target of many drugs that have been developed to treat the condition, such as Prozac. Yet around 95 per cent of the body's serotonin is produced not by the brain, but by the ENS, and is affected by what we eat, the state of our microbiome and the signals sent along the vagus nerve to the brain.

This mind-brain connection is now leading to new approaches to treating depression. Studies have found that sending electrical pulses along the vagus nerve can influence the brain's use of serotonin, helping to alleviate severe depression.

Until recently, fitting patients with the necessary pulse-generating implant required invasive surgery. But researchers at Harvard University and the China Academy of Chinese Medical Sciences have now developed a device that stimulates the vagus nerve

## BY STIMULATING THE GUT TO PRODUCE SEROTONIN, IT'S POSSIBLE TO AFFECT EATING BEHAVIOUR, ALLEVIATE ANXIETY AND EVEN ENHANCE BRAIN FUNCTIONING

externally, at the point where it's most easily accessible: the ear.

Tests of the clip-on device with 34 patients with clinical depression has already produced promising results, says research team member Dr Peijing Rong: "This non-invasive, safe and low-cost method of treatment can significantly reduce the severity of depression in patients."

Recognition of the key role of the vagus nerve in gut-brain communication is leading to other conditions being treated in similar ways – including obesity. In July, the journal *Proceedings Of The National Academy Of Sciences* published the results of an international study of vagus nerve stimulation among patients with the crippling disease rheumatoid arthritis, which affects half a million



# HOW TO HACK FAT

Wave goodbye to treating obesity with gastric bands and bypasses

The obesity epidemic sweeping the world has led to a surge in the use of bariatric surgery to help the most seriously obese. The idea seems simple enough: by removing up to 75 per cent of a patient's stomach, even small meals will be filling.

But studies of patients undergoing such operations have revealed a more subtle effect: the surgery also affects the vagus nerve connecting the enteric nervous system with the brain. This has opened the way to less radical methods of tackling obesity, by blocking the vagus nerve signals controlling appetite.

A study published earlier this year reported that by using an implanted device developed by US company EnteroMedics, obese patients lost around a third of their excess weight over a year, with a quarter losing at least 50 per cent. Researchers in France have now set up a trial to see if similar success can be achieved using a device that does not require surgery.



people in the UK alone. The technique, which currently requires an implant, appeared to benefit some patients by reducing inflammation in the body, a phenomenon also linked to many other conditions including ulcerative colitis and cancer.

Meanwhile, evidence is emerging for surprising links between the gut and other disorders usually thought to start elsewhere, such as Parkinson's disease. A team led by Dr Elisabeth Svensson at Aarhus University, Denmark, recently reported that patients whose vagus nerves had been severed to treat other medical conditions benefited from a substantially reduced risk of developing Parkinson's.

Work is now underway to understand this link, and use it to treat or even prevent the degenerative nerve disease. "To be able to do this will naturally be a major breakthrough," says Svensson.

## REAL-TIME DATA


The explosion of research interest in the ENS is impressive, but it's still early days in the quest to understand precisely how it works. Most of the trials of vagus nerve stimulation are pilot studies whose positive results may fade in bigger trials.

The sheer complexity of the gut-brain connection is daunting, says Dr Xiling Shen of Duke University: "Disorders like irritable bowel syndrome are only diagnosed by symptoms, but their causes and mechanisms are completely unknown." Together with colleagues at universities across the US, Shen is

working on a key tool for unlocking the mysteries of the body's second brain: a device capable of monitoring the action of the ENS in real time.

The prototype, which is currently being used in animal studies, features an electronic implant that can show how the ENS responds to different neurotransmitters, drugs and diseases. This is already casting new light on how the second brain interacts with the one in our skull. According to Shen, by stimulating the gut to produce serotonin, it's possible to affect eating behaviour, alleviate anxiety and even enhance brain functioning.

And this is just the start, explains Shen: "We are currently developing non-invasive ENS recording technology that will allow personalised and precision treatments."

At this rate of progress, we may all have to prepare ourselves for the day when our family doctor clips a device on our ear with the words: "I just want to check on the state of your second brain." 

**Robert Matthews** is visiting professor in science at Aston University, Birmingham.



DISCOVER MORE

Watch clips from a *Trust Me I'm A Doctor* episode about our gut microbes at [bbc.in/1PSmaLm](http://bbc.in/1PSmaLm)





# THIS IS WHY







# WE DANCE

As *Strictly* reaches its climax, millions of people will be tuning in to watch. But why are we such dance-lovers? Science might just have the answers...

Words: Dr Peter Lovatt





ancing is in our DNA. It is found in every culture around the world throughout history, and is enjoyed by people of every age, from toddlers to the elderly.

From a scientific perspective, dance is an important human activity. Actually, from *any* perspective dance is an important human activity. It's important for enjoyment, for interpersonal communication, for social bonding and for our general health and well-being as well.

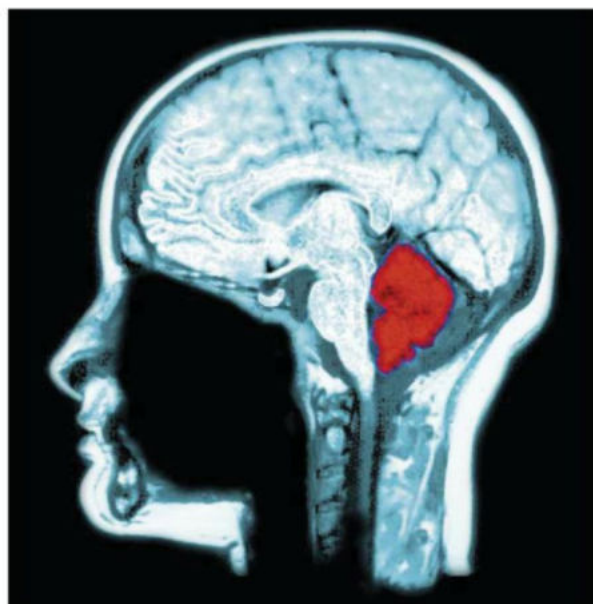
Scientists have long been interested in dance because it can tell us about our innate responses to music, about why some people get dizzy and others don't, about how we find a mate and about the very essence of being human. Dance is something that only we can do (no other animals on the planet can dance creatively like us), and which every human being is equipped for. If you love to dance, welcome to the club. Now let's find out *why* we dance...

### BOOGIE BRAINS

It all begins in our brains. The human brain is specialised for the control of movement – it needs to be, in order to manipulate our 600-plus muscles. The motor cortex, located at the rear of the frontal lobe, is involved in the planning, control and execution of voluntary movements. Meanwhile, the basal ganglia, a set of structures deep within the brain, works with the motor cortex to trigger well-coordinated movements, and may also act as a filter by blocking out unsuitable movements, such as that ill-advised funky chicken. The cerebellum, at the back of the skull, also performs several roles, including integrating information from our senses so that our movements are perfectly fluid and precise.

Just lifting a cup of tea to our mouths involves an unimaginably complicated sequence of nerve impulses, so how can our brains cope with a full-blown dance routine? In 2006, researchers at the University of Texas Health Science Center at San Antonio asked amateur tango dancers to perform a basic dance step known as a 'box step' while lying in a PET (positron emission tomography) scanner. The researchers saw activation in a region of the brain called the precuneus, which is associated with spatial perception. They suggest that this region creates a map of our body's positioning in space, helping us to keep track of our torso and flailing limbs as we plot our path across the dance floor.

RIGHT: Good at keeping time to a beat? Thank your cerebellum for that (highlighted in red)



Of course, dancing also tends to involve music. By comparing the tango dancers' brain scans both with and without music, the researchers noticed that those performing to music had more activity in a particular region of the cerebellum called the anterior vermis, which receives input from the spinal cord. It might be that this region of the brain acts as a kind of neurological metronome, coordinating our different brain areas and helping us to keep time to a beat.

Just like any activity, the more we dance, the better we get, as new neural connections are forged and strengthened. What's more, it seems that our brains may even reward us for having a good boogie. Music has been shown to activate the reward centres in the brain, and some motor areas are also connected to reward-related regions, so dancing can give us the satisfaction of feeling good. It's part of a virtuous circle: we generate rhythm, we move to it, we feel great, we do it some more. Let the good times roll...



**A GROWING BODY OF RESEARCH SUGGESTS WE ARE BORN TO DANCE. WHY ELSE WOULD WE MAKE OURSELVES LOOK SO RIDICULOUS AT SCHOOL DISCOS OR THE OFFICE PARTY?**





Bulgarian cave paintings dating back to the Bronze Age appear to depict ritualistic dancing

### BORN TO BOP?

We still don't know for sure whether humans have evolved an innate instinct to dance, or whether dancing is a learned social activity. Nevertheless, a growing body of research suggests that we are indeed born to dance. Why else would we make ourselves look so ridiculous at school discos or the work Christmas party, when we're desperately trying to impress someone?

To investigate whether dancing is an innate activity, researchers need to look at three factors. First, do humans show an *inclination* to dance – a **natural tendency, or an urge?** Second, is dancing *automatic* – ie, are people able to dance without being taught? And finally, is dancing *universal*? Do people from all parts of the world display dance-based behaviour?

This last one is easy: dance is truly universal, both in time and place. Anthropologists have shown that dance-like behaviour dates back thousands of

years. Early Bronze Age paintings in the Magura Cave in Bulgaria appear to depict a fertility dance, while dancing was an important part of life in Ancient Greece and Egypt. Dance has played multiple roles throughout history, in religious ceremonies, rituals and festivals, and as a way to heal, entertain and tell stories. It might even have served as an early form of language.

Meanwhile, there's also evidence that dancing is both a natural urge and an automatic behaviour. In 2009, researchers led by István Winkler at the Hungarian Academy of Scientists showed that **babies** as young as two days old are able to detect a simple beat. When the babies heard a missing downbeat, their neural activity suggested that they were expecting the downbeat to be present – so newborn babies appear to have an innate sense of rhythm. In a separate study in 2010, Marcel Zentner and Tuomas Eerola showed that older babies make more rhythmic body movements in response to ●

## THE SCIENCE OF DAD DANCING



The concept of dad dancing gets a bad press. Even its dictionary definition is disparaging: "Awkward or unfashionable dancing to pop music, as characteristically performed by middle-aged or older men."

In 2011, I carried out a survey of almost 14,000 people (including over 8,000 men), looking at dance confidence and dancing styles at different ages. I found that men's dancing confidence typically starts at a very low level in the early teens, steadily increasing with age, peaking and plateauing in the mid-to-late thirties before coming down again after 40. At the same

time, their freestyle dance movements tend to become larger, less coordinated and more random the older they get. Eventually, it's like they're dancing to music that only they can hear.

This slightly awkward dancing style may be evolution's way of signalling reduced testosterone levels, warning younger women that the dancer is past his sexual prime and that they might be better off looking elsewhere.

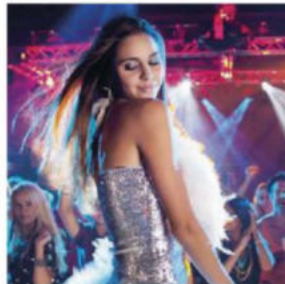
But men, don't let any negativity put you off. The benefits of dancing are enormous. In the name of science, we should reclaim dad dancing, rebrand it and embrace it.



# 5 REASONS WHY DANCING IS GOOD FOR YOU

## IT BOOSTS SELF-ESTEEM

Several studies have shown that dancing can help to increase feelings of self-worth. In one 2007 study, researchers from Laban and Hampshire Dance found that children aged between 11 and 14 who took part in creative movement classes reported improved self-esteem, motivation, and more positive attitudes towards dance, as well as better physical fitness.



## IT HELPS YOU FIND A MATE

It was Charles Darwin who suggested that dancing can act as a form of sexual selection, and research suggests that we are indeed communicating to potential mates when we strut our stuff. A 2011 study asked women to rate men on their dancing prowess. The winning formula? Head shaking, torso bending, and twisting of the right knee, apparently.



## IT TACKLES DEPRESSION

Dancing has been shown to reduce feelings of depression. But different dancing styles have different effects. In a study led by Andrew Lane at the University of Wolverhampton, dancing characterised by relaxed, free-flowing movements helped to improve mood, whereas dancing in a physically contracted way had the opposite effect.



## IT HELPS SOLVE PROBLEMS

Just five minutes of freestyle dancing is enough to increase your creativity, according to researchers at Sheffield and York Universities. In 2014, participants were asked to either dance, cycle or sit quietly while listening to music, and it was the dancers who showed improvements in both mood and creative problem solving.



## IT RELIEVES PAIN

Rugby is a tough game played by tough people. But some rugby players will dance before a game – just think of the New Zealand team's haka. In 2015, researchers at the University of Oxford found that group dancing can increase a person's threshold for pain. Dancing, it seems, can release endorphins, helping to take the sting out of a full-contact tackle.



AS WITH ANY INTENSE PHYSICAL ACTIVITY, DANCING CAN ALSO RELEASE ENDORPHINS – THE FEEL-GOOD, PAIN-RELIEVING BRAIN CHEMICALS RESPONSIBLE FOR THE SO-CALLED 'RUNNER'S HIGH'





ABOVE LEFT: Flash mobs aren't just good fun, they may help participants to bond too

ABOVE RIGHT: Grab your friends and have a dance if you want to enjoy a social high

• music than they do to human speech, and some even speed up their movements when the tempo is ramped up. The evidence all suggests that humans are hardwired to boogie.

### DANCING FOR JOY

If our brains are primed for dancing, it's no surprise that we love to get our groove on. But there's another reason, too: it's a fantastic mood enhancer. I've been drunk on disco, made merry by a merengue and felt the euphoria of dancing in a hot, sweaty nightclub. And it seems that everyone can experience that euphoria: Zentner and Eerola even found that their baby subjects smiled as they moved to the rhythm. The more they moved, the more they smiled.

So why does dancing make us feel better? It might be because as we move together in response to music, we also move in response to each other's rhythms, helping us to form a social bond. It's one of the reasons why we love music festivals. A 2010 study by Sebastian Kirschner and Michael Tomasello at the Max Planck Institute for Evolutionary Anthropology showed that after a session of paired music making, four-year-old children were more likely to behave cooperatively and helpfully. Music and dancing act as a kind of social lubricant, helping us to bond and form positive relationships.

As with any intense physical activity, dancing can also release endorphins – the feel-good, pain-

relieving brain chemicals responsible for the so-called 'runner's high'. In fact, Bronwyn Tarr and colleagues at the University of Oxford have found that just dancing in time with someone might be enough to release these neurohormones into the bloodstream. They asked Brazilian high school students to dance in groups of three to fast-paced music, finding that those who synchronised their movements had an increased pain threshold (as measured by inflating a blood pressure cuff around their arm). This suggests that there were more endorphins in these dancers' bodies, so the researchers speculate that we might get a social 'high' from dancing with others. That would explain flash mobs, at least.

Dance is one of the most important activities we can do. We are born to groove. It's what our brains are wired for and it helps us bond. Dancing is good for you. So this Christmas, throw caution to the wind and get your body moving to all those cheesy festive tunes. 🎶

Dr Peter Lovatt is a dance psychologist who runs the Dance Psychology Lab at the University of Hertfordshire.

DISCOVER MORE



Buy episodes of *Nature's Greatest Dancers* from the BBC Store at [store.bbc.com](http://store.bbc.com)



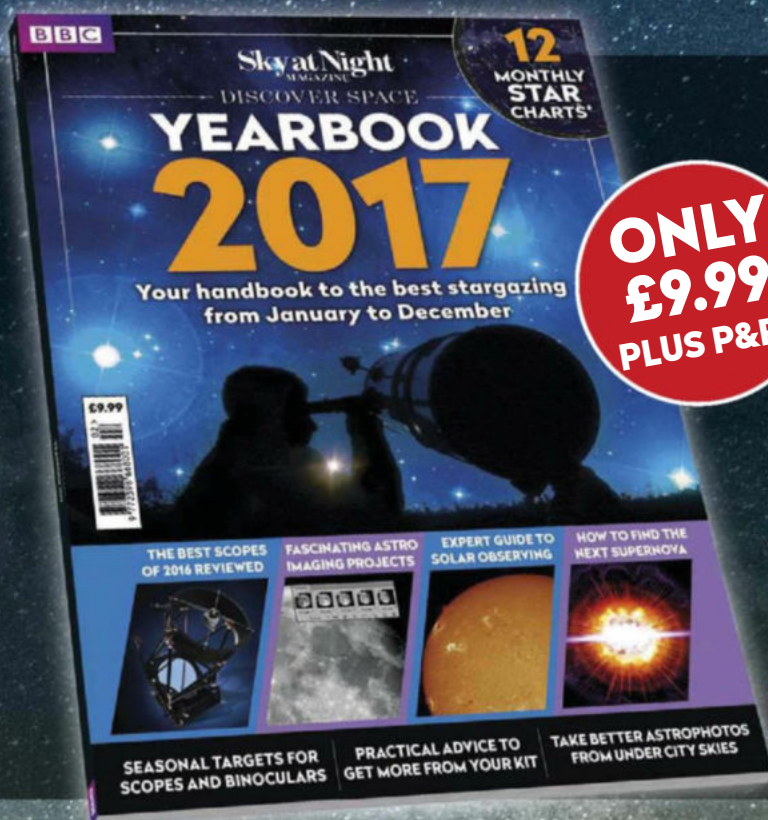
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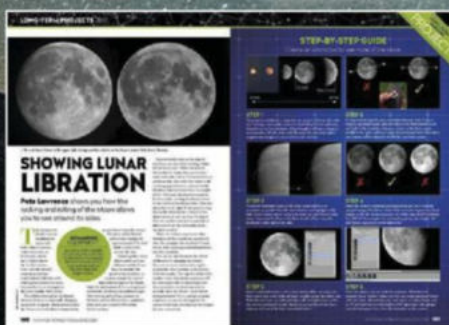
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HELEN CZERSKI... **WHY ISN'T 21 DEC THE COLDEST DAY?**

**"JANUARY IS AN UNFORGIVING TIME. BUT IF THE DAYS ARE GETTING LONGER, WHY'S IT GETTING COLDER?"**

**D**

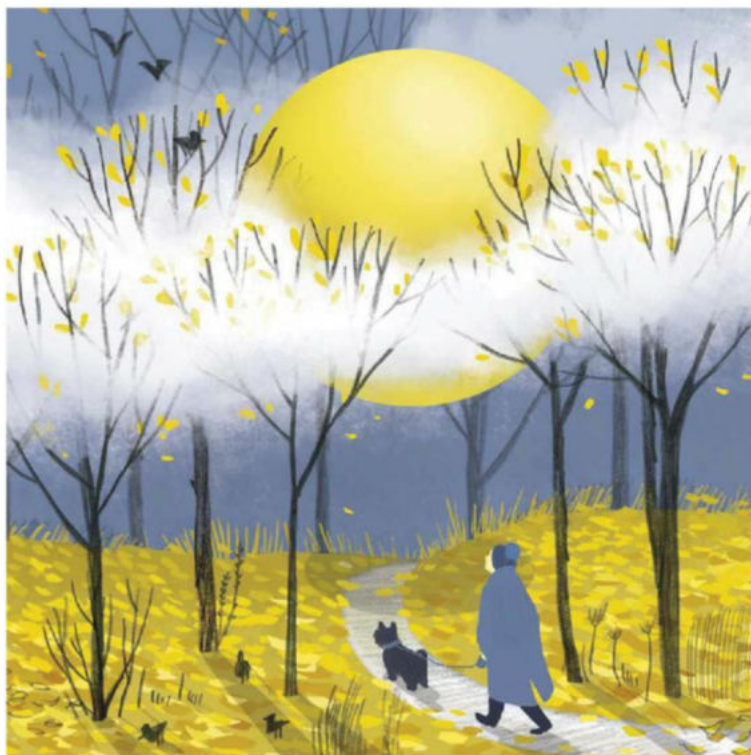
ecember is a cheerful month in an odd way: the slow and dismal retreat of the sunshine is offset by the arrival of beautiful frosty mornings, seasonal parties, hot chocolate and cosy evenings in.

When we arrive at the winter solstice, we reach the turning point of the year when the days start to get longer again. Surely that's something to celebrate? But instead, the gloom deepens. The coldest day of the year probably won't happen for another month, maybe longer, and January is a murky, unforgiving time. So if the day length is getting longer, why is it getting colder? Why isn't the shortest day of the year also the coldest?

We think of weather as being about what happens up in the sky, but the heart of this question is down in the ground. When you look out of the window on a sunny winter's day, you can see the surface of the Earth, but you can't see what's flowing in and out of it: energy.

The air around us is mostly heated by the ground, not by the sunlight itself. So on 22 December this year, the first longer day, slightly more of the Sun's energy is available to warm the ground, and the overall heat flow into the surface increases by just a little bit. But this doesn't make much difference, because the ground is losing heat much more rapidly than that. Rock and soil can store a lot of heat energy, but this energy is constantly leaching away. Air molecules close to the ground are being warmed up as they bump into the earth, and this warmer air is buoyant. It'll drift upwards through the atmosphere like a rising hot air balloon, taking energy with it. Any water that evaporates from the ground will also take a smidgen of energy away. And finally, the Earth is radiating away energy in the form of infrared light that we can't see (it's also absorbing a little bit of infrared from the atmosphere, but it's losing more than it's gaining).

It's all about the balance between heat flow in and heat flow out. In late December the ground is losing more heat than it's gaining from the Sun, and so it keeps getting colder. The days have to get much longer before the balance tips back the other way, and things start getting warmer again. A similar thing happens every day on a smaller scale – it's usually warmest at 3pm and not midday. It's only in the mid-afternoon



that heat loss starts to outweigh heat gain and the cooling can begin.

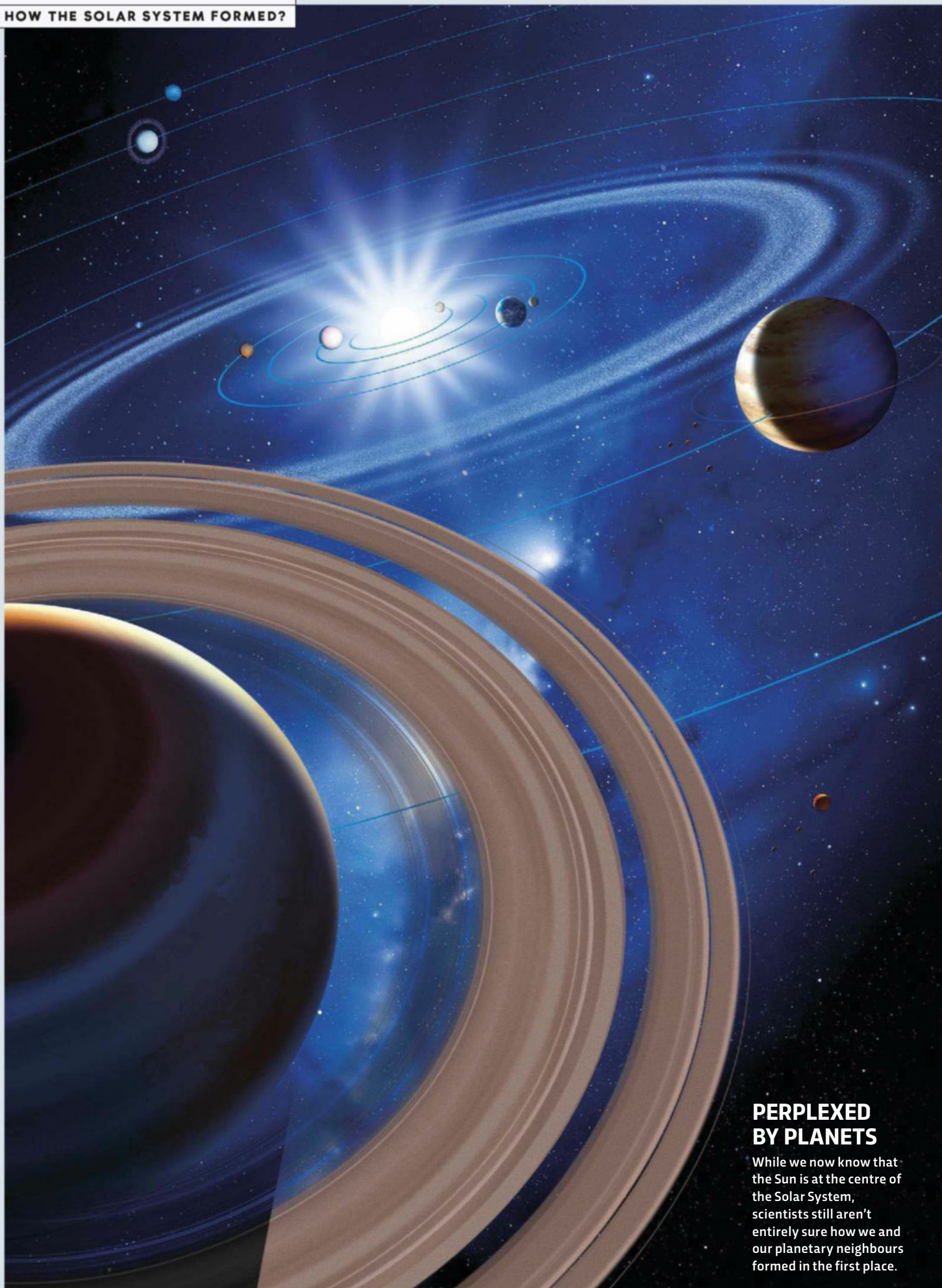
The other factor influencing the cold is your proximity to the sea. The Earth's oceans are massive heat reservoirs; closer to the coast, the water will be heating the air above it, keeping it (and you) warm. That's why the places that experience the greatest temperature extremes are all inland regions – they are a long way from the ocean heat buffer. But the UK is an island, so even in the country's coldest places, the ocean is still relatively close by, which helps you out a little bit.

As the dull January days loom up on the calendar, perhaps the optimistic thing to do is to take advantage of the northern hemisphere being tilted away from the

Sun. The long nights and clear, cold night air of winter offer us fantastic views of the stars. And even though the heat is leaching away into the sky as we watch the cosmos, we know that our orbit is returning us to sunlight, and the balance will tip back soon. ☼

**Dr Helen Czerski** is a physicist and BBC science presenter. Her book, *The Storm In A Teacup*, is out now (£8.99, Transworld).

**NEXT ISSUE: WHY DO RICE KRISPIES GO SNAP, CRACKLE AND POP?**



## PERPLEXED BY PLANETS

While we now know that the Sun is at the centre of the Solar System, scientists still aren't entirely sure how we and our planetary neighbours formed in the first place.

PHOTO: GETTY





# HOW DO WE KNOW...

## HOW OUR SOLAR SYSTEM FORMED?

From our prime position on the third planet out from the Sun, we're finally understanding how our solar neighbourhood came to be

WORDS: COLIN STUART

Asking questions about where we come from is one of the traits that marks us out as distinctly human. Yet this inquisitive streak hasn't always led us in the right direction, particularly when we think we are more important than we ultimately are. The story of our quest to discover how our Solar System formed is littered with false starts, and one that astronomers are still refining.

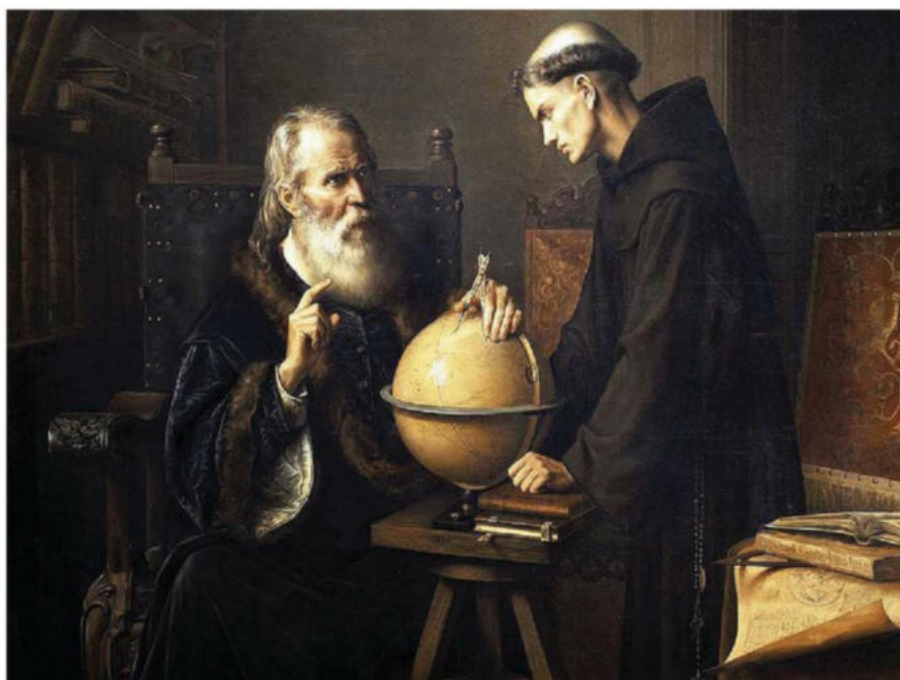
The world's greatest thinkers originally had the Earth at the centre of creation, with the Sun, Moon, planets and stars circling around us. It's an idea that lasted for more than 1,000 years, dating back to the days of Aristotle and Ancient Greece. It wasn't until the Polish astronomer and mathematician Nicolaus Copernicus challenged this idea in the 16th Century that the tide of opinion started to shift. He said that the planets – including Earth – orbit around the central Sun. Copernicus was so fearful of the inevitable backlash from religious quarters that he delayed publication of his work until after his death. Legend has it that he only saw a copy on his deathbed.

### Galileo! Galileo!

It would take many decades for experimental evidence to confirm

that we do indeed live in a 'solar system'. It was mostly the work of the Italian astronomer Galileo Galilei in the early 1600s that cemented the idea. It wasn't all plain sailing, of course. Galileo famously had his own run-ins with the Church, and he was only officially pardoned in 1992. But as far as the science was concerned,

the clincher came when he observed the planet Venus waxing and waning through phases, much like the Moon. This isn't possible if both Venus and the Sun orbit around the Earth – only if both planets circle a central source of illumination. So we took our place as just another one of the Sun's family of planets. ►



Galileo Galilei, as depicted in this painting by Felix Parra, explaining his astronomical theories to a friar at Padua University

➤ Attention then naturally turned to how such a system could come about. In the 1630s, the French philosopher René Descartes was one of the first to speculate. His starting point was the idea that nothing in nature could ever be empty. So if a particle in space moved position, another must move in to fill the gap, creating a series of 'vortices'. Descartes believed that the planets were formed when material caught up in these swirling circles somehow condensed. It would take Sir Isaac Newton and his famous work on gravity to establish *why* the planets orbit the Sun. But that still didn't explain *where* the Sun and its planets came from.

### Pick your theory

By the mid-1700s, French mathematician Georges-Louis Leclerc was suggesting that the planets formed when a comet struck the Sun, sending vast amounts of material surging outwards. Over time, he said, gravity collected this material together to form orbiting worlds. By the end of the century, Leclerc's compatriot Pierre-Simon Laplace had shown this to be impossible – any ejected material would have been pulled back in by the Sun's gravity.

Laplace himself then started to formulate an alternative picture. The

invention of the telescope had allowed astronomers to discover a series of fuzzy blobs scattered around the night sky. They called them 'nebulae', which is the Latin for 'clouds'. Laplace suggested that the Sun had formed from such a cloud. As the cloud collapsed under gravity it spun faster and faster, much like an ice skater drawing in their arms. According to Laplace, material would have been thrown off the Sun as its rotation quickened, creating a flat disc surrounding the star. The planets were then formed when gravity gathered this material together.

Yet by the turn of the 20th Century, Laplace's idea had all but been abandoned. The main problem was that if this picture was correct, the Sun should be spinning a lot more rapidly than it is, and the planets should be revolving at a more sedate pace. Unable to reconcile this issue, astronomers such as Sir James Jeans turned to an alternative explanation. In 1917, Jeans proposed that another star was involved in the Solar System's formation. As this intruding star buzzed past the Sun, its strong gravity would have torn off a significant amount of stellar material. That, said Jeans, provided the building blocks necessary to form the planets. But his idea didn't last ➤

RIGHT: Isaac Newton made the first reflecting telescope, which used a concave mirror to gather light. This replica of his design was made in the 1920s



## GLOSSARY

### Exoplanet

Any planet which orbits a star other than our Sun. The first exoplanet orbiting a Sun-like star was found in 1995.



### Migration

The idea that the orbits of planets in a solar system can shift considerably over time.

It is thought that Jupiter migrated inwards in our Solar System.



### Nebula

A large cloud of gas and dust in interstellar space. Some nebulae can be thought of as star factories. Over many millions of years, gravity slowly collapses the cloud until the temperature and pressure is sufficient to ignite a new group of stars.



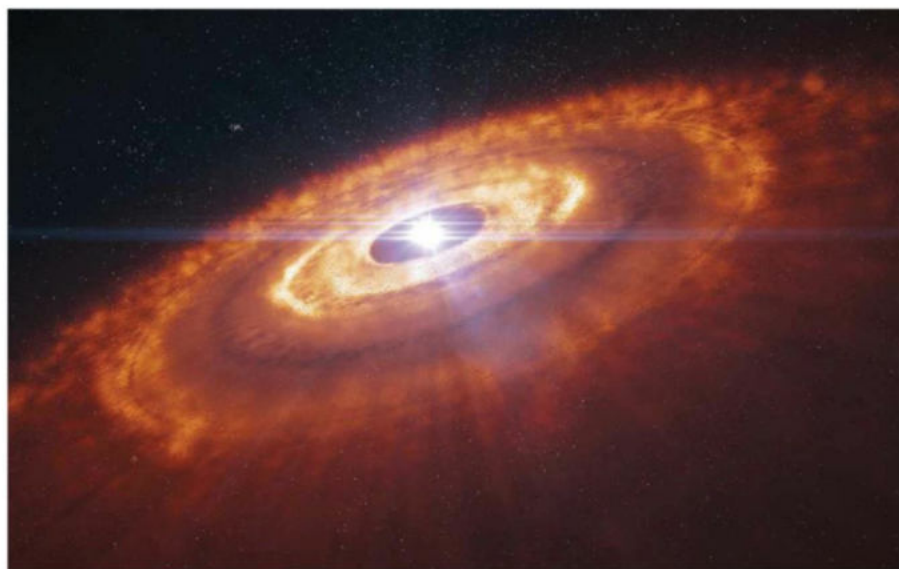
### Proplyd

An abbreviation of 'protoplanetary disc'. These are dark, flat rings around newly forming stars that astronomers believe will end up as planets.



### Vortex

A whirling mass of fluid or air, especially a whirlpool or whirlwind. Descartes believed a similar mechanism was responsible for why the planets orbit the Sun.



A young star is surrounded by a formation of dust and gas known as a 'protoplanetary disc', in which new planets are forming



# TIMELINE: THE SOLAR SYSTEM

Knowledge of our cosmic neighbourhood has come a long way since scientists first suggested that we may not be centre of the Universe

1543



## NICOLAUS COPERNICUS (1473-1543)

Born in Poland, Copernicus worked in many areas of intellectual thought from economics and politics to medicine, but is most noted for his work on the orbits of the planets.



1543

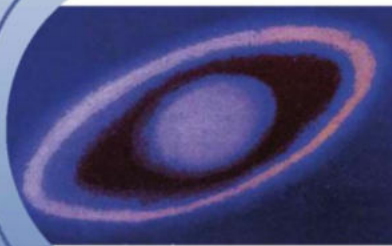
Copernicus publishes *De Revolutionibus Orbium Coelestium* (*On The Revolutions Of The Heavenly Spheres*) setting out his ideas of heliocentrism. It is one of the most important books ever written.

## GALILEO GALILEI (1564-1642)

The grandfather of modern astronomy, Galileo was the first person to point the telescope towards the night sky in a meaningful way, revolutionising our ideas about our place in space.



1796



1796

Pierre-Simon Laplace proposes his nebula model for the formation of the Solar System, which astronomers would return to over 150 years later.



## PIERRE-SIMON LAPLACE (1749-1827)

Not content with valuable work on star formation, this influential French scientist was one of the first to imagine the concept of a black hole – a star with strong enough gravity to prevent anything escaping.

1995



## SIR JAMES JEANS (1877-1946)

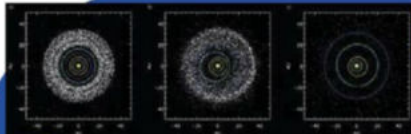
British astronomer James Jeans gave his name to the 'Jeans mass'. If a nebula reaches this critical point it will undergo irreversible gravitational contraction and trigger star formation.



1995

Astronomers discover the first planet orbiting another star like our Sun, ushering in the era of exoplanet astronomy which has seen over 3,000 new worlds discovered.

2005



2005

The first incarnation of the Nice model is published, the most comprehensive picture to date of how our Solar System came to be. It utilises the idea of planetary migration.



## MIKE BROWN (1965-)

As the self-styled 'Pluto Killer', Brown has been one of the most prolific discoverers of objects located beyond the orbit of Neptune. He is instrumental in the current hunt for Planet Nine.

2014

The first signs begin to emerge that there may be a ninth planet in our Solar System. Small, distant objects are discovered to have very similar orbits – something unlikely to be down to chance.



2014

Astronomer Fred Hoyle thought that the Sun could once have had a companion star – but this has been disproved



## THE KEY DISCOVERY

**Scientist: Nicolaus Copernicus**

**Date: 1543**

**Discovery: Earth and the planets revolve around the Sun**

It is hard to see how astronomers could have formed their current picture of how our Solar System came to be if we still thought everything orbited the Earth. Copernicus's breakthrough is rightly lauded as one of the greatest scientific revolutions in history.

And yet it wasn't inspired by astronomical observation, but by mathematical elegance. The ancient idea of geocentrism – that everything in the Universe orbited the Earth in perfect circles – ran into a problem when observing the night sky. Some of the planets appeared to double back on themselves – hardly the behaviour of worlds circling the Earth. So the Ancient Greek polymath Ptolemy introduced 'epicycles' which saw the planets move in smaller circles, which in turn orbited around the Earth.

But this was a big leap, introduced to force our need to have the Earth at the centre to fit with what we saw in the night sky. Copernicus's genius was to realise that switching to having the Sun in the centre would do away with the need for epicycles. Under his heliocentric model, Mars appears to double back on itself because the Earth overtakes it in its orbit around the Sun.



TOP LEFT: A chart of the Solar System, as described by Nicolaus Copernicus, with the central Sun

BOTTOM LEFT: Warsaw's Nicolaus Copernicus Monument has experienced notable history. After 1944's Warsaw Uprising, the Nazis removed it to melt it down, but had to retreat before the atrocity was committed

long. By 1929, it had been shown that such a close encounter was extremely unlikely due to the vastness of space. What's more, even if it did occur, the Sun would have reabsorbed much of the lost material. With no clear frontrunner, new theories continued to emerge as the decades rolled on.

In the 1940s, British astronomer Fred Hoyle proposed that the Sun once had a much larger companion star which had exploded as a supernova. Some of the resulting shrapnel was snared by the Sun's gravity, later coming together to form the planets. But that didn't hold water either, partly because it struggled to explain the low masses of Mercury and Mars.

It wasn't until the 1970s that things started to make more sense, when astronomers returned to Laplace's nebula theory. The main problem with this theory – that the observed rotation of the Sun was slower than expected – could be eliminated if drag caused by dust grains in the surrounding cloud had helped put the brakes on. This idea was then buoyed significantly in the early 1980s when astronomers spotted dusty, flat discs of material located around young stars, called protoplanetary discs or 'proplyds'. This effectively caught planet formation in the act elsewhere in space.

### Alien worlds

Observing other solar systems is now key to understanding how ours formed. But up until the mid-1990s no one had ever spotted a planet orbiting another star like the Sun. That changed in 1995 with the discovery of a world encircling the star 51 Pegasi. In the last two decades, astronomers have uncovered more than 3,000 planets in other solar systems – the so-called 'exoplanets'. But right from the get-go it was clear that these alien neighbourhoods weren't all perfect mirror images of our own. For example, 51 Pegasi's planet, which has since been named Dimidium, takes just over four days to orbit 51







Despite their distance from Earth, stars like 51 Pegasi are helping us understand more about our own Solar System

Pegasi. It is nearly eight times closer to its star than Mercury is to the Sun. What's more, Dimidium is around half the mass of Jupiter, making it a much bigger planet than Mercury.

Under the simple picture of planets forming from the debris of a newborn star, it is incredibly difficult to get such a giant world forming in such close proximity to its host. A more viable explanation is that the planet formed much further away from the star and then migrated inwards over time. Here was compelling evidence that planetary orbits were not fixed, but could wander significantly.

Bolstered by these discoveries, astronomers started to look at our own Solar System with fresh eyes.

In 2005, a decade after the discovery of Dimidium, a group of astronomers proposed the Nice model (named after the city in France where it was first formulated). The crux of this idea is that the giant planets of our Solar System – Jupiter, Saturn, Uranus and Neptune – started off much closer together. Over time, Jupiter moved inwards towards the Sun as the other three planets moved outwards. In some scenarios, Uranus and Neptune even swap order.

The movement of Jupiter towards the Sun would have scattered many smaller bodies, much like a dog running through a crowd of pigeons. Many of these runaways would have ended up in the inner Solar System,

creating a sharp peak in the number of meteors raining down on the rocky planets and their moons. And there is indeed evidence of a surge in impact activity on the Moon between 3.8 and 4.1 billion years ago (any evidence of impacts on the Earth would have eroded away long ago). The outward movement of Neptune would also have sent smaller bodies running further from the Sun, helping to explain the Kuiper Belt and Scattered Disc – two reservoirs of smaller objects in the outer reaches of the Solar System.


### A hidden planet?

However, while it was a major step forward, this original Nice model was far from perfect. When using a computer simulation to recreate the gravitational interactions between the four giant planets, astronomers only ended up with a Solar System that looked like ours around 3 per cent of the time. But with one small modification they could boost this to 23 per cent. The modification? The addition of a fifth giant planet. Yet we've only ever seen four giant worlds. So if we're to take this explanation seriously we need to be able to say what happened to this other planet. It could well have been ejected from the Solar System entirely during the migration of its neighbours – an orphan planet left to wander the black void of space. Astronomers have

already found some examples of these so-called 'rogue planets', so the idea is far from ludicrous.

But there is an alternative, more tantalising explanation: this fifth giant planet is still right here in our own Solar System, waiting for us to find it. The buzz around this possible world, dubbed 'Planet Nine', has been one of the most exciting astronomical developments of recent years. Back in 2014, a team of astronomers noticed that several small objects orbiting the Sun out beyond Neptune had very similar orbits. Then in January 2016 it was announced that more objects had been found behaving in the same way. The likelihood of such shared characteristics being down to chance has been calculated at just 0.007 per cent. The leading explanation is that there is an extra planet, at least 10 times more massive than the Earth, skulking in the dark and lining the small objects up by tugging on them with its gravity.

If Planet Nine does indeed exist, the reason it has escaped our notice so far is its sheer distance from the Sun. Its orbit carries it an estimated 1,200 times further from the Sun than the Earth, meaning it's likely to appear at least 600 times fainter than the dwarf planet Pluto. Unless you knew exactly where to look, it would be easily missed. A dedicated search is now underway to hunt it down.

These latest astronomical adventures show us that the story of our Solar System's formation is still very much a work in progress. We may have come a long way since the days of Ancient Greece, but there are still many chapters left to write. 

Colin Stuart (@skyponderer) is an astronomy writer and author of *The Geek Guide to Life*.

DISCOVER MORE



Watch clips from *The Sky At Night*, which is shown once a month on BBC Four [bbc.in/1FINHWR](http://bbc.in/1FINHWR)

**NEXT MONTH: UNDERSTAND THE HUMAN MICROBIOME**

Planet Nine is a huge planet that could be lurking on the outskirts of our Solar System



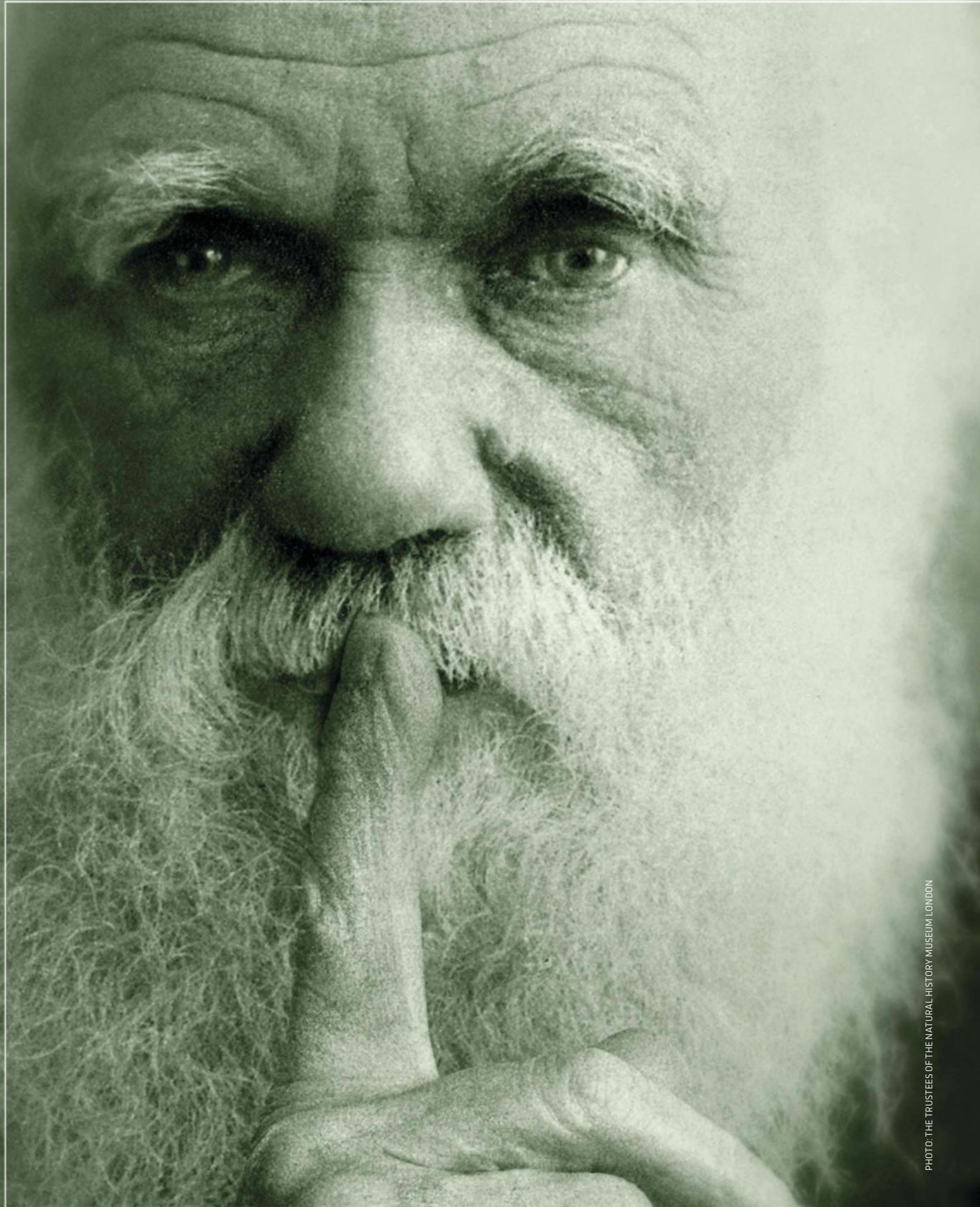


PHOTO: THE TRUSTEES OF THE NATURAL HISTORY MUSEUM LONDON



# ARE HUMANS STILL EVOLVING?

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WE MAY NO LONGER SUFFER THE EVOLUTIONARY  
PRESSURES THAT PLAGUED OUR ANCESTORS,  
BUT THIS DOESN'T MEAN MOTHER NATURE HAS GONE  
INTO RETIREMENT...

---

**WORDS: DR IAN RICKARD**

Ian is a lecturer in the anthropology department at the University of Durham. His research interests include evolutionary ecology, human biology and natural selection.

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# B

ack in 1965, Rudolph Zallinger created an illustration for Time Life books, which has been much-imitated and satirised. The original image, called *The March Of Progress*, depicted a chimpanzee-like creature on the left, and ended with what can be fairly described as a healthy-looking and athletic man of European ethnicity on the right. The message from this influential image and its title was clear: human evolution is a progressive march from primal origins to the final, all-singing, all-dancing, all-Tweeting specimens that we are today. We represent the pinnacle of Mother Nature's achievements. She can now rest, her work being at an end, with the creation of a being that has mastery over its own fate. Human evolution now appears to be over.

Except it isn't – not by a long way. In fact, it will never be over, nor could it be. Evolution is something that is happening all the time in all populations of all species on the planet. The word 'evolution' simply means 'cumulative change', with biological evolution referring specifically to changes in allele frequencies

in populations. Alleles are different versions of the same gene, and their distribution changes all the time. This is because new mutations arise in the genetic code and individuals move between populations. Sometimes, the changes are simply down to chance. And when any of these happen (and they always happen), biological evolution is occurring.

#### ENDLESS EVOLUTION

It may be technically true that evolution is continually occurring due to these processes, but when most people ask whether or not evolution is taking place, there's often another process they're thinking of: natural

selection. This is what happens when some alleles spread because individuals that have them 'survive, thrive and multiply' better than others, passing on those alleles to their descendants, who spread them further. It is natural selection that spreads adaptations: anatomical, physiological or behavioural traits which enable an organism to multiply in its environment. The apparent logic of these adaptations, of the functional fit between an organism's trait and its environment, is intuitive and intelligible to human minds. It has fed into countless creation myths over the ages, and most recently has enabled construction of a predictive scientific framework that unifies many strands of the natural sciences. Because of adaptations, natural selection has implications that range from the behavioural sciences to public health.

At first, there would appear to be good reason to suspect that evolution due to natural selection has now come to a halt. Following industrialisation and the benefits gained from better medical knowledge and improved infrastructure, many populations around the world have gone through something called the 'demographic transition'. This phenomenon is characterised by infants becoming more likely to survive to adulthood, adults living longer, and a reduction in fertility rates.

However, natural selection requires that some individuals survive, thrive and multiply whereas others don't – it needs variability. It has been argued that the demographic transition removes the variability on which natural selection depends. Yet it is incorrect to say that humans as a whole must not still be evolving because of this, as child mortality is unfortunately still significant in many places. Despite some fantastic progress in recent decades, there are still 30 countries, mostly in sub-Saharan Africa, with under-five mortality rates of more than 5 per cent (UN 2015 figures). Any alleles that are likely to help a child make it through that critical time to his or her fifth birthday will be under strong selection in those populations.

So assuming current trends continue, could child mortality in developing countries become as low as it is in Europe? Unlikely. While the total opportunity ●

**Evolution is a progressive march from primal origins to the all-singing, all-dancing, all-Tweeting specimens of today**

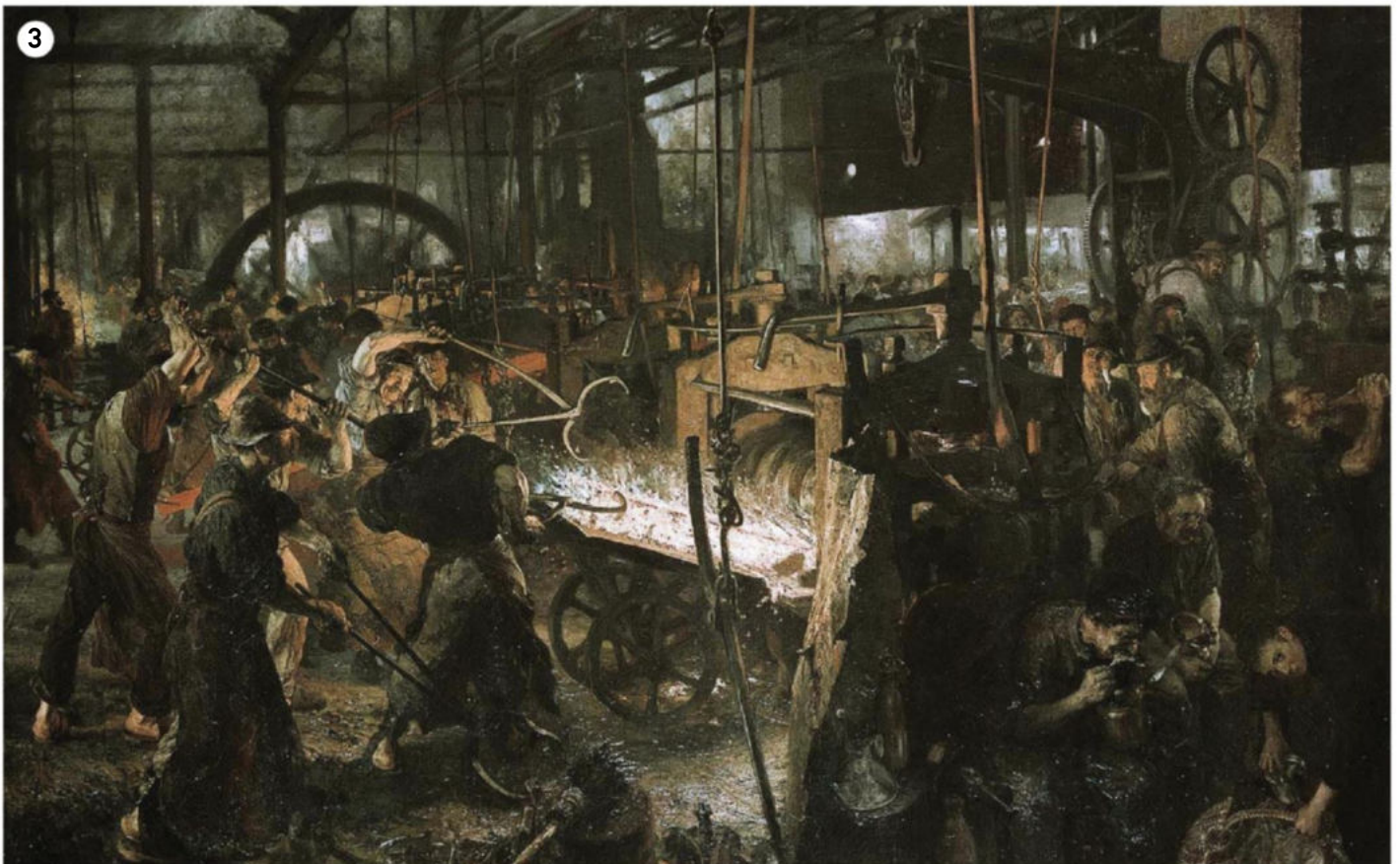
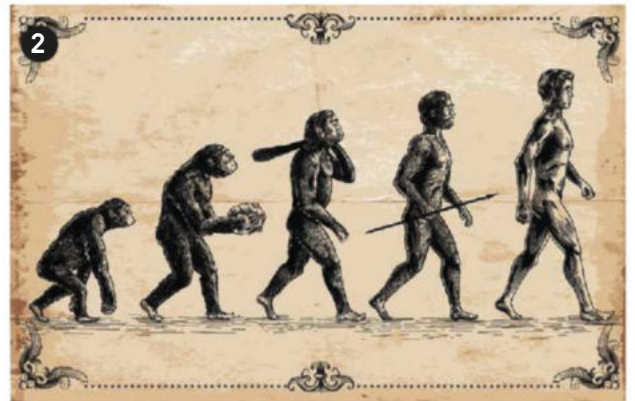




**1** In many countries, people are having children later in life – this may become more common as evolution selects for this ability

**2** Zallinger's 1965 drawing *The March Of Progress*, the illustration that spawned a million satirical imitators

**3** Industrialisation, depicted here by painter Adolph Menzel, changed many of the factors that affect the process, but natural selection is still taking place





If child mortality rates continue to fall in developing countries, natural selection may affect those populations in new ways



If you can happily drink milk as an adult, then you've inherited a mutation that allows your body to process lactose

● that natural selection has to occur goes down as children's survival prospects increase, such dramatic changes can lead to natural selection affecting a population in new and unexpected ways.

One example is the birth rate of fraternal twins. Generally, twin babies are smaller than singletons. Because of this, prior to modern medical technology and practice, they usually had lower survival prospects. Twinning often didn't really pay, in evolutionary terms. Quite why twinning occurs at all, we're not sure, but now the disadvantage of twinning is disappearing. As it runs in families, we can predict

that those alleles associated with fraternal twinning will become more common over time, now that twin babies are more likely to survive and reproduce themselves. That fraternal twinning may become far more common is one of the least outlandish claims that can be made about future human evolution.

#### FAMILY PORTRAIT

Natural selection operates on the variability of the ability of alleles to 'survive, thrive and multiply'. Even in societies in which mortality is very low, natural selection may still be a strong force due to variability in how much individuals reproduce. Individuals who do not have

children contribute no more to the population genetically than someone who dies before becoming reproductive. In the US and several European countries, almost one in five women entering menopause do so having not reproduced. This is partly due to individual preference. According to data from 2011, in four European countries – Switzerland, Germany, Austria and the Netherlands – at least 1 in 20 people aged between 18 and 40 express a desire for childlessness. In Dutch men, it is one in six. These are not insignificant numbers, and they suggest that childlessness may be both a normal feature of human populations and one whose rate varies partly depending on the social values that people hold.

However, it also appears that childlessness may to a larger extent be an unintended outcome. It is partly related to the age at which someone attempts to start a family. In women, variation in the age at which fertility declines and menopause begins is influenced by genetic factors, and so may be a driver of evolutionary change. Say we have two friends: Angelina and Brienne. Both try to start a family in their early forties but Angelina has alleles that enable her to successfully conceive at that age, whereas Brienne does not. This means it is Angelina's alleles, and not Brienne's, that will be present in future generations. The more it becomes common for people to start families later in life, the stronger the selection will be for the ability to reproduce at those ages, although this will take many generations to come about, and the strength of such an effect will be dampened by the use of reproductive technologies.

Although choice is clearly important in the decision of whether, and at what age, to have children, it would be a mistake to overlook factors that are

***The more people start families later in life, the stronger the selection will be for the ability to reproduce at those ages***





Twins may become more common in the future, as more survive childhood and reproduce themselves

beyond the individual's control. Even a stated preference for childlessness may be one that an individual expresses reluctantly as one of life's difficult choices. Family planning decisions are also the product of the constraints of the sociocultural environment that people live in, such as the financial cost of childrearing, the availability of family and friends to help with children, the stability of one's relationship with a romantic partner and the effort and time required to invest in one's career. Such factors combine with societal norms attached to having a certain number of children to affect individual reproduction.

## CULTURE CLUB

These social and structural features of the environment that all humans experience in some way are part of what anthropologists call culture – the values, beliefs, practices and technologies that we find in any given society. Delayed parenthood is something that emerges from the behaviour of individuals, but it is a response to a culture present in a particular time and place, and just as quickly as it has become common, it could in the future become rare, if that culture changed. The fact that culture is a ubiquitous and highly variable feature of all human lives provides another example of why our evolution is not over. The idea that scientific knowledge and technology – products of culture – insulate us from selection is just plain wrong. They can to an extent insulate us from nature, but nature isn't the only source of selection, particularly for humans.

Culture both originates from, and impacts upon, human beings. Thus human behaviours, through the technologies and practices that they have collectively

created, have themselves been the selective forces that have influenced human evolution. Regardless of how well we might think we've tamed nature, the fact that we create our own environments will continue to provide avenues for selection to occur.

A great historical example of this is the ability to digest the milk sugar lactose in adulthood. If you can comfortably drink milk, you're more of an oddity than you might think. Milk is essentially mammalian baby food, and most adult mammals lose the ability to produce the milk-digesting enzyme lactase when they become adults, as there is no benefit for adults to produce it, only costs. However, just a few thousand years ago when people in parts of Africa, Europe and Asia began herding cattle and goats, those few individuals who were born with mutations that enabled them to digest milk as adults were at an advantage. Through this characteristic of 'lactase persistence', these mutant individuals were able to exploit an additional food source. Within those herding populations, mutant individuals and their descendants survived, thrived and multiplied, and over time became more common than the non-mutants who continued to lose the ability to digest milk as adults.

In fact, we can even see the evolutionary marks of culture on all human bodies. All humans get their nourishment through the use of technology of some kind, from the simple digging tools and open fires of our ancestors to the combine harvesters and gas hobs of today. It looks as if prehistoric hominins effectively 'outsourced' their mechanical and chemical digestion, and as a result they could afford to put less energy into developing a complex digestive system. Whereas our closest ape relatives have strong robust teeth and jaws to break down tough plant material, and a long small intestine for nutrient absorption, our bodies have evolved to let technology do the hard work for us. We have culture literally in our bones.

So rather than having escaped the forces of selection in recent decades and centuries, it turns out that we were, in a way, controlling our own destiny all along by introducing sources of selection ourselves. We have had some kind of mastery of our destiny for millions of years, but rather than having escaped the forces of evolution, we find that we are just enmeshed in an intricate relationship with them. Rather than being separate from nature, we find that we are of nature, and will always be, whatever progress we feel we may have made: a march maybe, but certainly not one with an end. 📍

## DISCOVER MORE



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## ROBERT MATTHEWS ON... **THE BENEFITS OF EXERCISE**

***“DESPITE THE RELENTLESS FOCUS ON WEIGHT, IT’S OUR LACK OF FITNESS THAT’S LIKELY TO DO US IN”***

**O**ur ancestors had a great way to boost morale at this time of year. Just when days are literally at their darkest, at the time of the winter solstice, they’d have a huge celebration, and eat themselves rigid.

The exact timing may have slipped a bit, but what we now call Christmas is still a time for blowouts. What has changed is our attitude towards it. When we muster the courage to get on the bathroom scales a week later, we’re appalled to find that 500g of chocolate has somehow turned into 3kg of body fat.

Everyone knows what we have to do: get the weight off, and keep it off. After all, research has shown beyond doubt that getting fat is a recipe for an early grave. But it’s now becoming clear there’s a far more serious health threat that many of us should fix first: a lack of physical activity.

Despite the relentless focus on weight, it’s our lack of fitness that’s likely to do us in. Amazingly, a recent European-wide study found that inactivity is responsible for twice as many deaths as obesity.

Fortunately, there’s some good news. Research has also shown that our risk of everything from heart disease and stroke to dementia, type 2 diabetes and even some cancers plunges by at least 30 per cent with just a bit of moderate exercise each day. Indeed, the effect is so dramatic that the prestigious Academy of Medical Royal Colleges (AoMRC) recently described physical exercise as a “miracle cure”.

The trouble is, getting the benefits is not as easy as popping a pill. According to official guidelines, it takes 150 minutes a week of getting a bit breathless and sweaty for the miraculous benefits to appear. And for



many people that’s 149 minutes more than they want to devote to it.

It doesn’t have to take up so much time. There are get-fit-quick strategies like High Intensity Interval Training (HIIT), which cram a lot of activity into just a few minutes a day. But all this conjures up images of chubby types leaping on their new exercise bike and dying of a heart attack 30 seconds later. That’s why even staunch advocates of fitness programmes say you should see your doctor before starting.

Cue finger-wagging by the AoMRC – not at us, though, but at doctors.

Everyone knows that, unless you’re blessed with iron self-discipline, after a few wet days or late nights our exercise routines tend to fall apart.

Those studies revealing the benefits of exercise all had scientists constantly monitoring their

patients to make sure they stayed the

course. But already hard-pressed

family doctors are hardly in a position

to set up and monitor fitness

programmes for their patients.

Not good enough, says the AoMRC. The benefits are simply too big for the medical profession to ignore: “Exercise is a miracle cure too often overlooked by doctors and the people they care for”.

All this would doubtless have baffled our ancestors. They’d struggle to understand why we fret about putting on a bit of extra weight while ignoring our fitness level. For them, being fit was literally a matter of life and death – not least because it determined whether they got to eat at all.

Happily, we no longer have to catch our Christmas dinner. But it’s becoming clear that unless we walk rather than sleep it off, this year’s blowout could be our last.

Robert Matthews is visiting professor in science at Aston University, Birmingham.

**NEXT ISSUE: SUPERSYMMETRY**



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scientist, author



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Zoo director,  
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writer



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Neuroscientist,  
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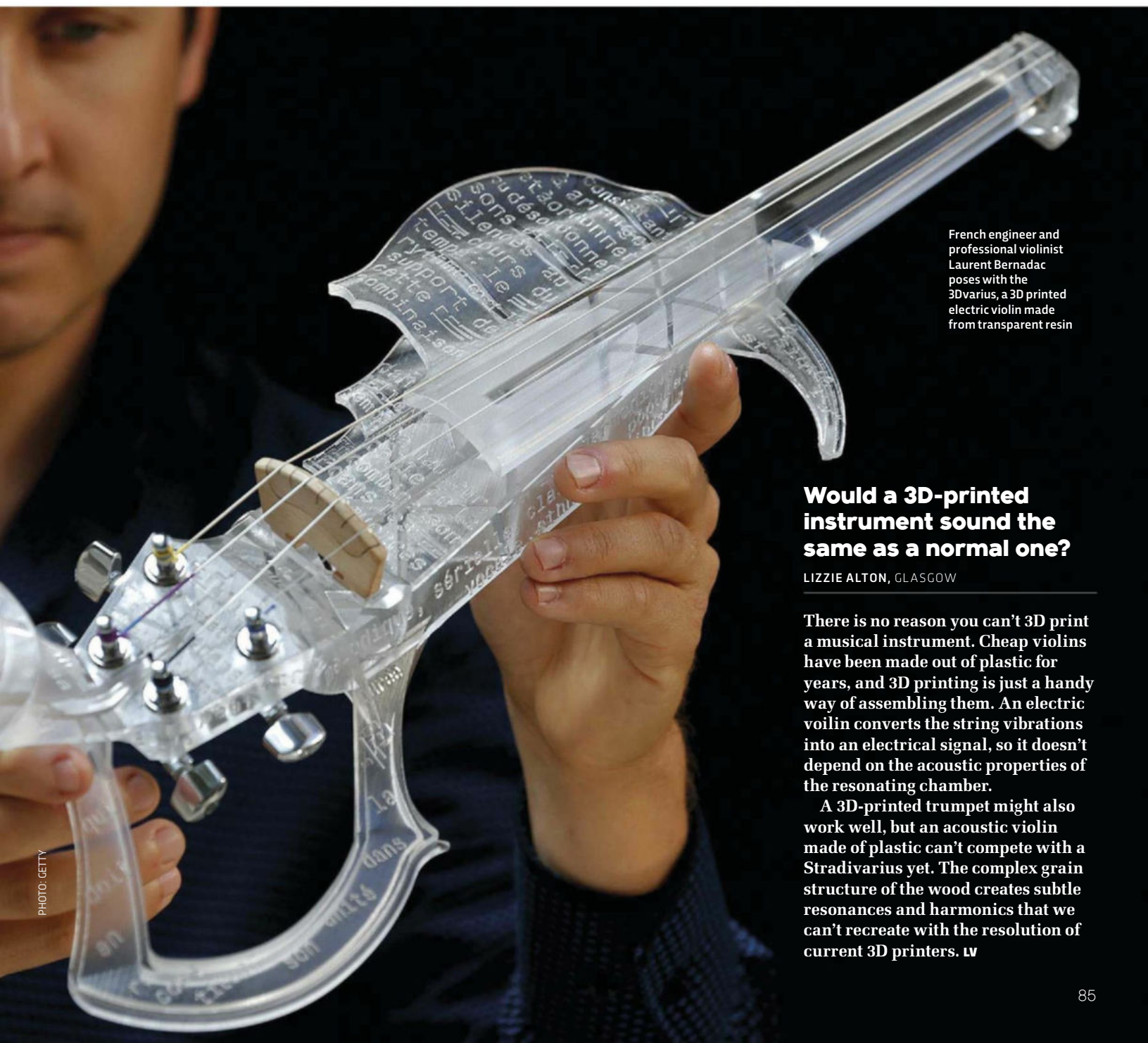


**PROF ROBERT MATTHEWS**  
Physicist,  
science writer

# YOUR QUESTIONS ANSWERED

CHRISTMAS 2016

EDITED BY EMMA BAYLEY



French engineer and professional violinist Laurent Bernadac poses with the 3Dvarius, a 3D printed electric violin made from transparent resin

## Would a 3D-printed instrument sound the same as a normal one?

LIZZIE ALTON, GLASGOW

There is no reason you can't 3D print a musical instrument. Cheap violins have been made out of plastic for years, and 3D printing is just a handy way of assembling them. An electric violin converts the string vibrations into an electrical signal, so it doesn't depend on the acoustic properties of the resonating chamber.

A 3D-printed trumpet might also work well, but an acoustic violin made of plastic can't compete with a Stradivarius yet. The complex grain structure of the wood creates subtle resonances and harmonics that we can't recreate with the resolution of current 3D printers. **LV**



## Do identical twins think alike?

MANISH PARMAR, USA

The genes we inherit from our parents influence our psychological characteristics – things like our intelligence and memory ability – and our chances of developing conditions that affect the way we think, such as autism and schizophrenia. In that sense, identical twins – who share all the same genes – do think more alike

than unrelated people or even non-identical twins and other siblings. Brain-imaging research has shown that during mental tasks, such as memorising numbers, the patterns of brain activity (which can be considered a physical correlate of thought) are more similar among identical twins than non-identical twins. **cj**

## Are there different types of earwax?

RALPH TALBOT, CHICHESTER

Just two. The most common, wet earwax, evolved as a way to remove dead skin cells from your ear canal. Earwax is 60 per cent skin, with various different oils binding it together in a brown lump. But there is a recessive gene mutation that results in a different mix of oils, giving grey and flaky earwax. This dry earwax is common among the Japanese and Native Americans. Coincidentally, having dry earwax also means you produce less armpit odour. **lv**



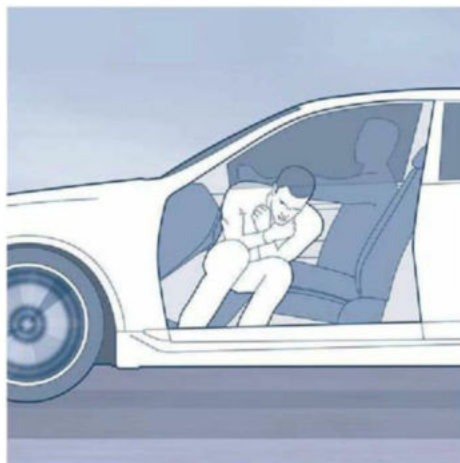
### THE THOUGHT EXPERIMENT

## HOW CAN I JUMP SAFELY FROM A MOVING CAR?



### 1. TIMING

'Safe' is unrealistic. However, you can make it *survivable* with a little bit of planning. If you are sitting in the left seat, wait until the car is travelling around a bend to the right, so you will be thrown clear of the car. Make sure there are no oncoming signposts.



### 2. ANGLE

To protect your elbows, stuff your sleeves with paper or anything you can find. Crouch in the footwell, facing the door. Push the door open and jump out at a 45° angle. Pull your elbows in and put your fists under your chin. Keep your legs together and don't try to land on your feet.



### 3. IMPACT

Aim to land on your back. This is the widest part of the body and will spread the impact force most evenly. Keep your limbs and neck tensed to prevent them flailing, and allow your body to roll. Resist the urge to put your hands out, otherwise you will break your wrists.



# WHY DO WE DREAM?

THOMAS FURNESS, LONDON



People with damage to the brain's parietal lobe, which integrates sensory information, don't dream. One hypothesis suggests that while we sleep, the parietal lobe continues generating signals, and our forebrain tries to make a story out of this activity.

Other researchers have suggested that dreams occur when short-term memories are

encoded and moved to long-term memory, or when unwanted connections are removed from memory.

Evolutionary psychologists contend that dreams have a specific survival value. We mostly dream about threats or stressful situations. This may be so we can safely rehearse strategies for dealing with them. **LV**

## IN NUMBERS

# 27

The number of genes on the human Y chromosome. In comparison, the X chromosome has around 1,000.

# 13

The speed, in km/h, that cyclists should travel at while commuting, to avoid breathing in too many pollutants. Those who cycle faster inhale up to four times as much air pollution because they breathe more heavily.

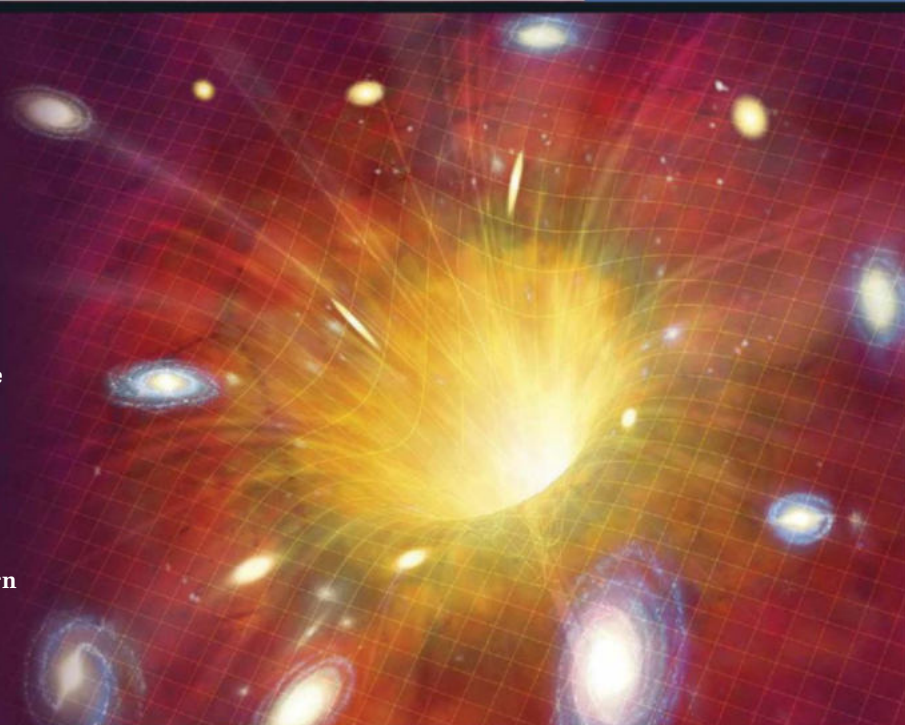
# 24

The number of distinct academic families that two-thirds of the world's mathematicians fall into.

## Would the Big Crunch collapse everything – matter and space-time?

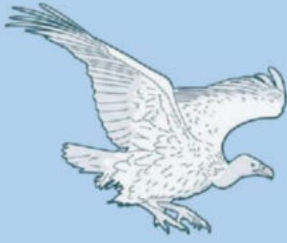
HENRY PARR, BRISTOL

Although the 'Big Crunch' idea is currently out-of-favour with cosmologists, it is still one possible fate for the Universe. However, the eventual endpoint of the Big Crunch is not known. In simple terms, if we regard it as the opposite of the Big Bang, we might indeed expect that all matter and space-time itself would collapse into a 'singularity': an infinitely dense point similar to that from which the Universe appears to have sprung. But singularities are notoriously difficult notions to investigate scientifically, so modern physics can say very little about what might ultimately happen during the Big Crunch. **ac**



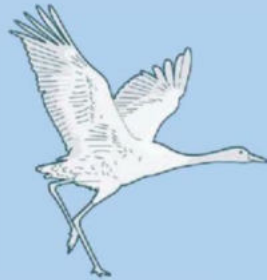
## TOP 10

## HIGHEST FLYING BIRDS

**1. Rüppell's griffon vulture**

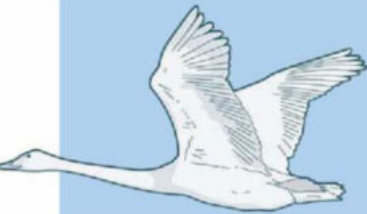
Altitude: 11,300m

Distribution: Sahel region, Africa

**2. Common crane**

Altitude: 10,000m

Distribution: Northern Europe and Asia

**3. Whooper swan**

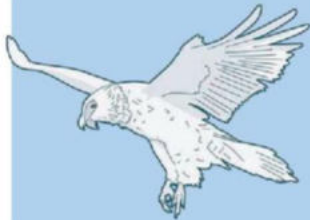
Altitude: 8,200m

Distribution: Europe and Asia

**4. Alpine chough**

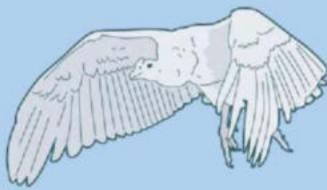
Altitude: 8,000m

Distribution: Mountains from Spain to China

**5. Lammergeier**

Altitude: 7,300m

Distribution: Mountains in Europe, Asia and Africa

**6. Andean condor**

Altitude: 6,500m

Distribution: Andes, South America

**7. Bar-headed goose**

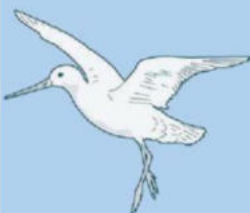
Altitude: 6,437m

Distribution: Central and South Asia

**8. Mallard**

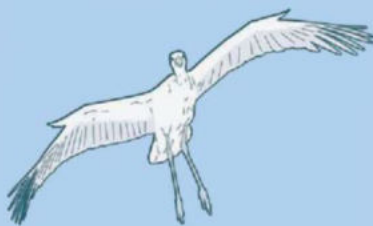
Altitude: 6,400m

Distribution: Europe, Asia and North America

**9. Bar-tailed godwit**

Altitude: 6,000m

Distribution: Northern Europe, northern Asia and Alaska

**10. White stork**

Altitude: 4,800m

Distribution: Europe, North Africa and western Asia

**Why do hard-boiled eggs sometimes get a grey ring round the yolk?**

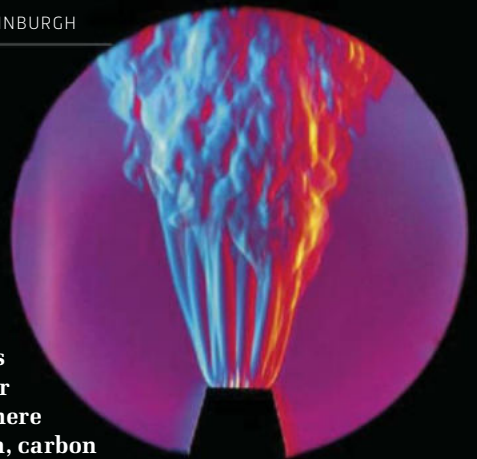
CHRISTINE ELLIS, LEEDS

Egg white is 92 per cent water, with a mixture of around 148 different proteins, mainly ovalbumin, ovotransferrin and ovomucoid. At room temperature, these proteins are held in a complex 3D globular structure by sulphur bonds between the amino acids in the protein chain. When the egg cooks, the heat causes the sulphur bonds to come undone so each protein molecule unravels and gets tangled up with its neighbours in a solid mass. This process happens at 77°C for ovalbumin. But above 70°C, the sulphur also forms hydrogen sulphide that reacts with iron in the egg yolk to form iron sulphide, and this gives it a greenish grey colour. You can prevent this by running the eggs under the cold tap to lower their temperature as soon as they are cooked. **LV**

**Why are gases invisible?**

THOMAS MCLAUGHLIN, EDINBURGH

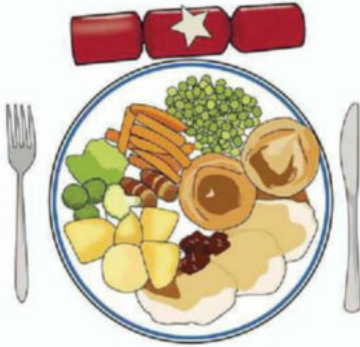








Actually, gases aren't invisible: many are quite brightly coloured. For example, nitrogen dioxide is brown-y orange, chlorine has a yellowish green hue and iodine vapour is a vivid purple. Other gases in the atmosphere (particularly oxygen, carbon dioxide and water vapour) also absorb light, but at ultraviolet and infrared wavelengths that we can't see. There's a sweet spot between the absorption spectra of oxygen and water where not much light gets absorbed. Lo and behold, that's exactly the range of light that we've evolved to see! So it's not that gases are invisible, as such, it's just that we can't see atmospheric gases as they don't have a colour in the visible range. **ML**





# WHAT HAPPENS TO YOUR BODY AFTER EATING CHRISTMAS DINNER?

As you prepare to start your festive feasting, it's probably best not to think about the discomfort that may follow. Here, we remind you of what lies in store in the 24 hours following your day of overindulgence. Recent South African research suggests one Christmas meal could fuel a 1.7-day hike in the Himalayas. But don't focus on the calories – this is a day of celebration! **ED**

	<p><b>FIRST 5 MINUTES</b></p> <p>Alcohol absorbs rapidly into the bloodstream and will hit you five to 10 minutes after your first sip. The small intestine absorbs most of the alcohol, while 20 per cent enters through the stomach. Alcohol dilates blood vessels, particularly the capillaries under your skin, making you feel warm.</p> 	<p><b>20 MINUTES</b></p> <p>The average stomach capacity is around one litre, but it takes 20 minutes for 'full' signals to reach the brain from the gastrointestinal tract, after you first starting eating. By then, you may already have overeaten. Eating and drinking too fast makes you belch as you swallow excess air.</p> 
<p><b>30 MINUTES</b></p> <p>As you eat, the food hikes up your blood sugar levels. In response, your pancreas will start producing the hormone insulin, which will convert the glucose into a storable form called glycogen. The resulting drop in your blood sugar levels makes you feel overwhelmingly tired.</p> 	<p><b>ONE HOUR</b></p> <p>After eating, more blood flows to the digestive tract. To aid digestion, your heart and metabolic rate go up, accompanied by a slight increase in body temperature, making you sweat and feel more tired. To make matters worse, rich foods are harder to process, and alcohol slows digestion.</p> 	<p><b>TWO HOURS</b></p> <p>A heavy meal rich in protein and fat can sit in your stomach for two to three hours, making you feel bloated. Flatulence is partly triggered when the body's enzymes can't deal with certain substances such as raffinose, a complex sugar found in Brussels sprouts and other brassicas.</p> 
<p><b>THREE HOURS</b></p> <p>It takes about three hours for the body to break down a 250ml glass of wine, but you've probably drunk more than that. Is it time for the cheeseboard? Combined with the carbs in crackers, the amino acid tryptophan in cheese could make you crash out.</p> 	<p><b>SIX HOURS</b></p> <p>It takes six to eight hours for food to pass through the stomach and the small intestine, before reaching the large intestine. The body digests meat into amino acids, which are absorbed through the small intestine and into the blood.</p> 	<p><b>24 HOURS</b></p> <p>With any luck, your hangover, caused largely by dehydration from alcohol's diuretic nature, will have eased by now. The body may finally start eliminating undigested food, having absorbed water and minerals, and stored excess fat.</p> 



# WHERE'S EINSTEIN?

The world's most famous physicist wandered into the Focus office Christmas party by mistake... can you find him?

Illustration by Jamie Coe

Tell us which scientists you've found on Twitter @sciencefocus











## Will I weigh less if I move to the equator?

CHRIS BRYSON, BRIXHAM

As our planet bulges at the equator, its gravitational pull there is lower than in the UK. Better still, the effect of the spin of the Earth at the equator also helps offset the force of gravity. The bad news is that even the combined effect would reduce your weight by less than 1 per cent – so it's probably easier, all told, just to cut back on the beer and pies. **RM**

## If you hold in a fart, where does it go?

ALISON STUDLEY, LONDON

It stays right there! Fart gas mostly comes from the bacteria and yeasts that live in the large intestine. If you suppress a fart, it actually just seeps out more quietly, or you might be able to hang on until the next time you are on the toilet. But sooner or later, that fart is coming out! **LV**



## Will it ever be possible to build a space elevator?

MAX JONES, NEW YORK

First proposed over a century ago by the Russian astronautical pioneer Konstantin Tsiolkovsky, the space elevator offers a whole new way of getting into orbit. Instead of using rockets, electric lifts travel up a cable anchored at the Earth's equator and extending up to an orbiting counterweight whose motion keeps the cable taut.

But while simple in concept, the practicalities are immense. Chief among them is the need for a cable material that's capable of withstanding the colossal tension. It's long been thought that carbon nanotubes would be up to the job, but new research by a team at Hong Kong Polytechnic University has shown that a single misplaced atom in the cable could radically undermine its strength. With no real prospect of creating a defect-free cable, the search is now on for more robust materials. **RM**



## Why does reading make you sleepy?

SACHIN SHAW, BIRMINGHAM

Typically when we're reading, we do it in a comfortable position – sitting or lying down – in a quiet place, and often at the end of the day or after more energetic activities, all of which contributes to a state of relaxation and sleepiness. Also, an absorbing text will take your focus away from the outside world and from anxieties that might otherwise keep us alert, such as worries about tomorrow's exam or dentist appointment. Alternatively, if you find what you're reading boring, the effort to keep going can be tiring, in which case you'll likely begin to daydream, which can also bring sleep closer. **Q**





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## What happens at absolute zero?

STEPHEN WEST, TYNE & WEAR

In one sense we can never know because reaching absolute zero is an impossible task as an infinite amount of work is required to cool something down that far. However you can get close – the world record coldest temperature is 0.0000000001°C above absolute zero. At super cold

temperatures strange things start occurring. Exotic states of matter appear, such as superfluids that have no friction and viscosity and so climb out of their containers; superconductors which have zero electrical resistance, and Bose-Einstein condensates, where atoms act totally in unison and never collide. **ML**



The high sides of Vindskip act as sails

## What's the biggest robot in the world?

SARAH MELLISH, ST ALBANS

According to the *Guinness Book Of Records*, the largest walking robot in the world is reported to be Tradinno, a 15m-long dragon robot weighing 11 tons that was used in a German theatre for the play *Drachenstich*. Powered by a two-litre turbo diesel engine, it can breathe flames to a distance of 1.5 metres. However, in the future, this dragon will be like a toy compared to the 200m-long robot container ship *Vindskip* planned for construction, which would traverse the seas using its giant sides as sails, and its computer brain to keep its course. **PB**

"Come and have a go!  
It smells lovely!"

## Why do dogs like rolling in fox poo?

LUIGI SEBASTIANO, BY EMAIL

One theory is that it's a hunting behaviour that evolved as a way to mask the dog's own scent to make it easier to stalk prey. It's odd that a dog would choose the poo of another

predator though. It may be that for most dogs, fox poo is the only really stinky poo they have access to. Cows and horses are kept away in their own fields and cats bury their poo neatly. **LV**

## How do we predict meteor shower intensity?

SIMON FOSTER, BURNLEY

Most 'predictions' of the rate of meteors per hour during meteor showers are based on both theory and observation. Essentially, a computer model is built containing the trajectories of every known comet – since it is the debris from comets that forms the 'stream' of particles we see during a meteor shower.

This model contains information on the rate that these comets release material, along with the sizes, directions and velocities at which they are released, as well as the gravitational forces that determine their subsequent trajectories through space. The trajectory of the Earth and the conditions of the Earth's

atmosphere are also inputted into the computer model.

By watching how Earth moves through the meteor stream it is possible to estimate the likely number of meteors that will be visible during a given shower for a given location. But different astronomers use different models. Plus, these models are partly based on difficult measurements of the meteoric particles in the Solar System, so their predictions are often only approximate. But generally, they can be used to reliably predict when a meteor shower is likely to be more or less intense than the average. **AG**

### WHAT CONNECTS...

#### ...BANANAS AND PROSTHETIC LIMBS?

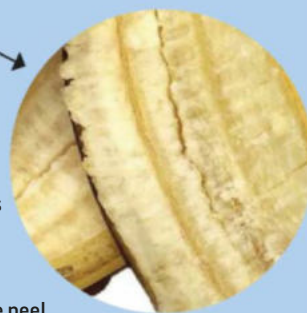
# 1.

A discarded banana peel is extremely slippery. The friction between the peel and a smooth floor is six times lower than between the floor and your shoe.



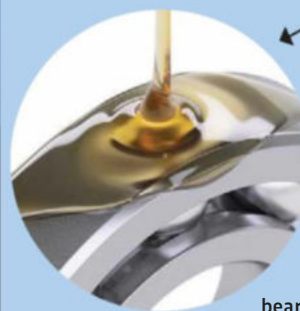
# 2.

The slipperiness comes from the follicle cells on the inside of the peel. When they are crushed underfoot, they release a polysaccharide gel between the floor and the peel.



# 3.

This gel is so slippery, it is actually a better lubricant than the oil used in metal bearings. It's only slightly less slippery than a ski on snow!



# 4.

Polysaccharide gels are also found in the membranes covering our bones at the joints. Research into banana peel slip-ups is helping to improve the design of joints in prosthetic limbs.







## QUESTION OF THE MONTH

# Will we ever be able to log onto Facebook with our minds?

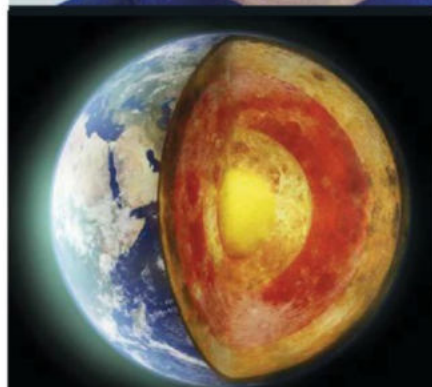
PAD SCANLON, LONDON

## WINNER!

Pad Scanlon wins a BT 8500 Nuisance Call Blocker (£59.99, [bt.com](http://bt.com)). The virtual assistant screens all incoming calls, completely blocking cold callers and nuisance numbers.



Surprisingly, the answer is yes. Research at Binghamton University in the US found that every person has a unique pattern of brain activity when shown a series of images. In the study, a computer measured the brainwaves of 45 volunteers and was able to determine the identity of each person with 100 per cent accuracy. This means that your 'brain print' could be a very effective way to enable secure login to computer systems, including Facebook. The only problem remaining is how to measure your brainwaves in an easy way – right now you need to wear a special hat full of sensors and wires. **PB**



## Will Earth's interior ever become solid?

RILEY BRIGHTWELL, CORNWALL

Beneath us all is a seething cauldron of rock, wrapped round an iron-nickel core at temperatures similar to the surface of the Sun. Most of the heat comes from radioactive decay of elements like uranium in the surrounding mantle. As this process will continue for billions of years yet, the Earth is likely to have been destroyed by the death of the Sun before it can solidify. **RM**

## How long before extra calories show on the scales?

JOYCE BURLEY, HULL

If you step on the scales as soon as you have eaten a jam doughnut for lunch, you will weigh an extra 70g, because this is the mass of the doughnut itself. But 22g of this is water, which you'll lose over the next few hours in your breath and urine. You'll lose another 2g sometime tomorrow, when you poop out the small amount of dietary fibre. The other 46g is digested and if your body doesn't immediately need it to grow or for energy, it is stored as fat. A 2012 study at Oxford University found that the fat in your food ends up on your waistline in less than four hours. Carbohydrate and protein take a little longer, because they need to be converted into fat in the liver first and it takes nine calories of protein or carbohydrate to make 1g of fat. Altogether, that doughnut has about 225 calories. Around 100 of those come from the 11g of fat in the doughnut, which will be on your waistline by teatime. Then the 125 calories of carbs and protein will be converted into another 14g of body fat sometime tomorrow, unless you hit the gym after work and burn it off again. **LV**



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Could the Black Death return?

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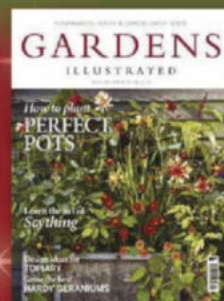
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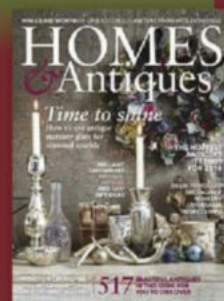
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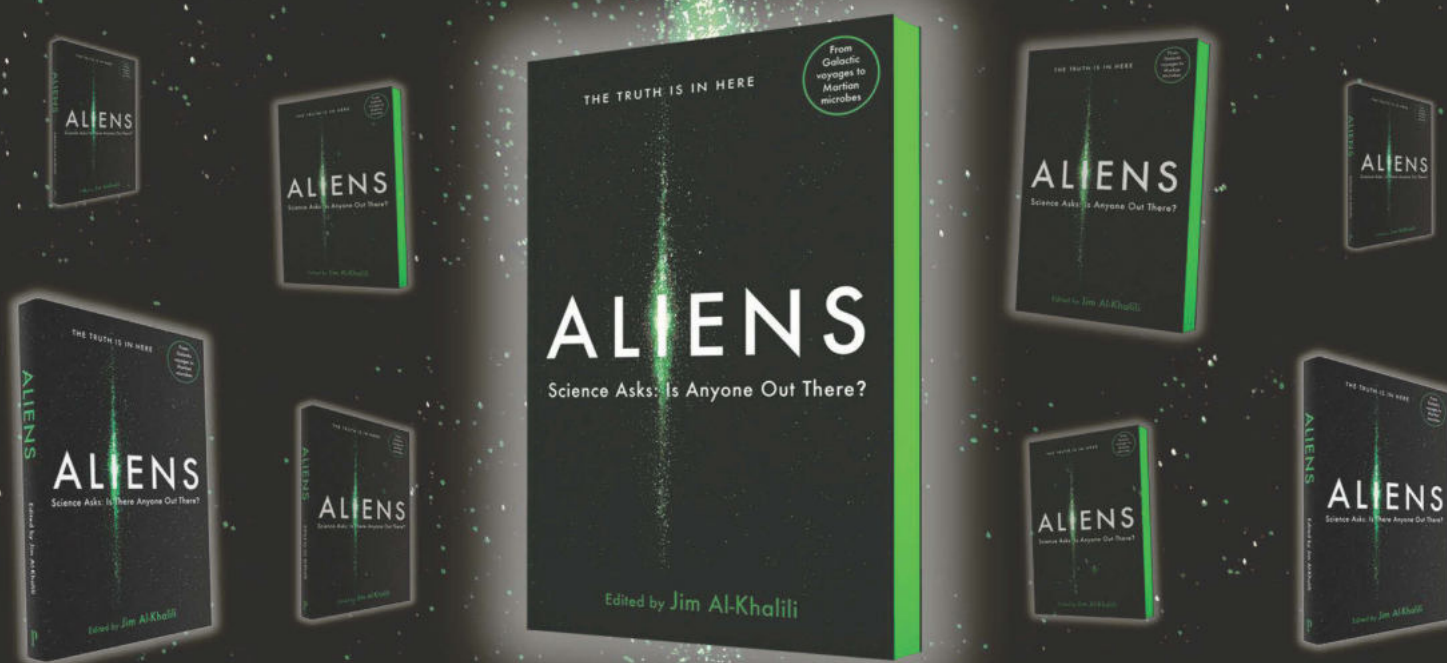
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## ROBIN INCE ON... **FACIAL HAIR**

**“ONE STUDY FOUND THAT WOMEN JUDGED FACES WITH HEAVY STUBBLE AS THE MOST ALLURING”**

**I**t's been said that men with beards have something to hide. From what I can tell, that 'something' is mostly discarded soup, and they're not doing a very good job of it.

Beards have rarely been as popular as they are now, but they're also an attribute by which other people may judge us, with the beardless often dismissing the hirsute as shallow hipsters. Personally I'm just glad that my own youth coincided with an era of shaven faces, because my chin foliage has a distinctly Steptoe air.

Christmas is a time of many beards. But why does Father Christmas have a beard, and not Mrs Christmas? In *The Descent Of Man, And Selection In Relation To Sex*, Charles Darwin – another great beard icon – contemplated the evolution of male facial hair. He saw it as a characteristic related to sexual selection, akin to a deer's antlers, a peacock's tail or a mandrill's colourful rump. This was facial hair as a testosterone-driven decoration that aided attraction and procreation – but has modern research upheld this belief?

A 2015 study by psychologists at Northumbria University examined the two oft-mooted 'sexy' traits of beards and growling voices. Filming men over four stages of beard growth, from clean-shaven to a month's growth, and with four pitches of voice, from a 50Hz raise in the pitch to a 50Hz lowering, they asked volunteers to rate men on their attractiveness and dominance. Although men with more facial hair were rated as more dominant, the researchers found no link with the men's perceived attractiveness. Those with lowered voices, on the other hand, were rated as both more attractive *and* dominant, so any wannabe alpha males might want to work on that Barry White impression.

Bearded Casanovas shouldn't give up hope, though, as previous research *has* found a link between facial hair and attractiveness. One study, published in the journal *Evolution And Human Behavior* in 2013, found that women judged faces with heavy stubble as the most alluring, perhaps because it




signals masculinity but not *too much* masculinity. Fully bearded men, on the other hand, were generally perceived to be better fathers, and more healthy.

So the jury's still out on the benefits of a beard. Incidentally, Darwin himself apparently grew his beard so that he wouldn't be recognised.

Unfortunately, this backfired and it was soon the most recognisable feature of the ape-man caricatures that adorned many newspapers following the publication of *On The Origin Of Species*. Today, of course, luxuriant beards are very much on-trend. So what's driving this cycle? According to a study published in *Biology Letters* in 2014, facial hair fashions can also be explained by Darwinian selection.

Researchers at the University of New South Wales in Australia asked participants to rate the attractiveness of male faces at four different levels of hairiness. The results showed that the more common beards became, the less attractive they were. On the other hand, when the number of clean-shaven faces increased, beards became more popular again. This is a phenomenon known as 'negative frequency-dependent sexual selection', where rare traits are preferred by mates. It also links us to male guppies, whose bright colouration is driven by the females' changing preferences.

So have we reached peak beard yet? Will beard oil and moustache wax be enjoying boom sales this Christmas? Or will badgers be staying in their setts for fear that they'll be plucked for shaving brushes? All

will be revealed if you hide near the fireplace on 24 December. A clean-shaven Santa Claus would be a strange sight, but at least it would make it easier to get all that soot off his face on Boxing Day. 

**Robin Ince** is a comedian and writer who presents, with Prof Brian Cox, the BBC Radio 4 series *The Infinite Monkey Cage* [bbc.in/1Lxp3QR](http://bbc.in/1Lxp3QR)

**NEXT ISSUE: GOOD AND BAD HABITS**

# OUT THERE

WHAT WE CAN'T WAIT TO DO THIS MONTH

CHRISTMAS 2016

EDITED BY JAMES LLOYD



PHOTO: UNIVERSITY OF BRISTOL





01 **HOLLOW**  
ROYAL FORT  
GARDENS,  
UNIVERSITY OF  
BRISTOL.

## EXPLORE A FOREST OF 10,000 TREES

As far as forests go, this is one of the more unusual ones we've stepped inside. Each of these pieces of wood has been gathered from a different tree – 10,000 in total, from almost every country on the planet, and spanning millions of years of history. Together, they form *Hollow*, a public artwork by Scottish artist Katie Paterson and architects Zeller & Moya at the University of Bristol.

Visitors are invited to step inside this miniature forest (there's enough space for one or two people at a time), taking a moment out of the daily grind to think about the stories that these trees might tell. There's also an accompanying website featuring a beautifully rendered version of the artwork and information on each of the tree species.

Katie Paterson's art often takes inspiration from science. Previous projects have included a necklace made from fossils, a scented candle that smells of space, and a reflection of Beethoven's *Moonlight Sonata* from the surface of the Moon.

Visit *Hollow* for free at the University of Bristol's Royal Fort Gardens.  
[hollow.org.uk](http://hollow.org.uk)



# 02 SETTLE DOWN IN FRONT OF THE BOX

THE ROYAL INSTITUTE CHRISTMAS LECTURES AND THE ENTIRE UNIVERSE ARE BOTH ON BBC 2 OVER CHRISTMAS.

When Michael Faraday created the Royal Institution Christmas Lectures in 1825, London was lit by gas lamps and George IV was on the throne. Nearly 200 years on, the lectures are still going strong, and the theme this year is a timeless one: energy.

Our host in 2016 is Saiful Islam, Professor of Materials Chemistry at the University of Bath. In *Supercharged: Fuelling The Future*, he looks at energy in all its forms, asking where it comes from, how we should use it and how we can store it for future use. Saiful's expertise is in state-of-the-art materials, so he'll be exploring the latest advances in clean energy devices such as solar cells and hydrogen fuel cells.

This year also marks 80 years since the lectures were first televised, so expect recreations of some of the most memorable experiments from lectures past.



Meanwhile, if you tune in to *The Entire Universe*, you could be forgiven for thinking that someone's spiked your eggnog. It all starts typically enough: Prof Brian Cox is giving a lecture on the birth of the Universe. But he soon realises he's part of a musical, starring none other than *Monty Python* legend Eric Idle.

A one-off special from the creators of *Spamalot*, the show sees Warwick Davis playing the part of the Big Bang, Noel Fielding as Einstein and Hannah Waddingham as Time. Meanwhile, Robin Ince attempts to keep order as Brian and Eric embark on their all-singing, all-dancing journey through space and time.

"I've made many documentaries over the years, and a constant complaint has been that the music is too loud," says Brian. "This undermines my credibility as a serious scientist. I expect *The Entire Universe* to be the final nail in the coffin."



03

# CURL UP WITH A GOOD BOOK

Puzzles, particles and plesiosaurs... here's our pick of books to keep your brain active over the festive season

## FOR THE NATURALIST

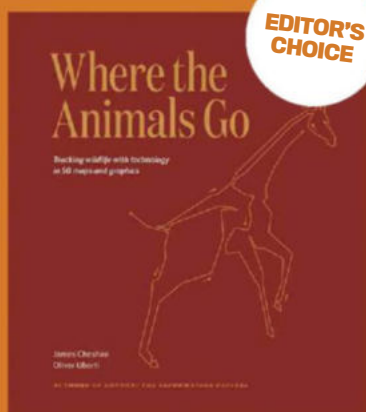


### THE INVENTION OF NATURE

ANDREA WULF  
(£9.99, JOHN MURRAY)

Winner of the 2016 Royal Society book prize, this biography of Alexander von Humboldt is an engrossing read. Find out why they named mountain ranges, an ocean current and even a penguin after him.

## FOR THE WILDLIFE LOVER



EDITOR'S CHOICE

### WHERE THE ANIMALS GO

JAMES CHESHIRE & OLIVER UBERTI  
(£25, PARTICULAR BOOKS)

Track the migration of 50 animals across land, sky and sea with this beautifully produced book. The authors have made use of the latest tagging data to create intricate maps of these epic journeys.

## FOR THE DINOSAUR MAD

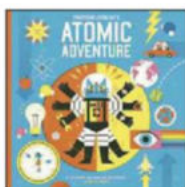
### DAY OF THE DINOSAURS

STEVE BRUSATTE  
& DANIEL CHESTER  
(£14.99, WIDE EYED EDITIONS)

Everyone loves dinosaurs, especially when they look as gorgeous as this. A comprehensive overview of dino history, this is the perfect gift for little monsters.



## FOR THE BUDDING EINSTEIN



### PROFESSOR ASTRO CAT'S ATOMIC ADVENTURE

DOMINIC WALLIMAN  
& BEN NEWMAN  
(£15.99, FLYING EYE BOOKS)

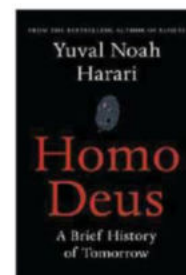
Introduce kids to the wonderful world of physics with this colourful guide. Aimed at ages 7-11, it makes the most mind-bending concepts accessible, from nuclear fusion to the multiverse.

## FOR THE THINKER

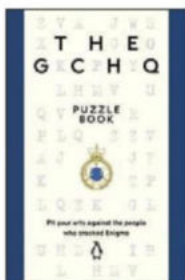
### HOMO DEUS

YUVAL NOAH HARARI  
(£25, HARVILL SECKER)

Where is the human race heading? The Israeli historian tackles this question with clarity and style in this wide-ranging follow-up to his bestselling *Sapiens: A Brief History of Humankind*.



## FOR THE PUZZLER



### THE GCHQ PUZZLE BOOK

GCHQ (£12.99, PENGUIN)

Flex your codebreaking muscles with GCHQ's first book of brainteasers. There are ciphers and substitution codes, as well as numeracy and literacy tests – plus hints for when you, inevitably, find yourself stuck.

## FOR THE TRAVELLER

### ATLAS OBSCURA

JOSHUA FOER, DYLAN THURAS  
& ELLA MORTON  
(£25, WORKMAN PUBLISHING)

Fancy disappearing down a nuclear bunker? How about a trip to the Garden of Cosmic Speculation? *Atlas Obscura* is your essential guide to the world's lesser-known travel destinations.



## FOR THE PHYSICS BUFF



### UNIVERSAL: A GUIDE TO THE COSMOS

BRIAN COX & JEFF FORSHAW  
(£25, ALLEN LANE)

Ponder upon cosmology's biggest questions while sipping your glass of sherry, from what happened before the Big Bang to what the Universe is made of.

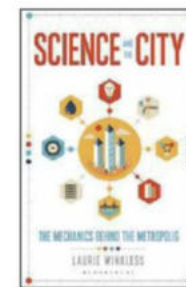


## FOR THE URBANITE

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LAURIE WINKLESS  
(£16.99, BLOOMSBURY SIGMA)

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04

## BID FAREWELL TO DIPPY (UNTIL 2018)

An old visitors' favourite is moving on from the Natural History Museum, but it's not too late to catch a final glimpse – she's going on a nationwide tour

**DIPPY**  
IS AT LONDON'S  
NATURAL HISTORY  
MUSEUM UNTIL  
4 JANUARY.

Ever since the grand unveiling in 1905, the colossal skeleton of Dippy the Diplodocus has been one of the stars of the Natural History Museum, and she's welcomed visitors to the Hintze Hall since the 1970s. So there was something of a commotion when the museum announced last year that Dippy was due to be retired.

But it's not goodbye for good. The last chance to see this replica skeleton in London will be 4 January 2017, but Dippy is already gearing up for a UK tour. Beginning in early 2018, Dippy will be visiting eight carefully selected locations across the UK, including Dorchester, Rochdale, Belfast, Glasgow and Cardiff.

Meanwhile, replacing Dippy in the Hintze Hall from summer 2017 will be the real skeleton of a blue whale, suspended from the ceiling. Name suggestions on a postcard please...

For full details of Dippy's UK tour, visit [bit.ly/2eAA5yY](http://bit.ly/2eAA5yY)



PHOTOS: NATURAL HISTORY MUSEUM X2



# SYLVIA FRÜHWIRTH-SCHNATTER SHARES HER FAVOURITE PLACES IN VIENNA



## 1 KARLSPLATZ

This large square is a major transport and tourist hub in central Vienna.

## 2 KARLSKIRCHE

Located on the south side of Karlsplatz, this church is one of the city's most spectacular buildings. Kreuzherrengasse 1 [karlskirche.at](http://karlskirche.at)

## 3 WIENER MUSIKVEREIN

Concert hall, home to the Vienna Philharmonic, and the city's most famous place to see live classical music. Musikvereinsplatz 1 [musikverein.at](http://musikverein.at)

## 4 CAFÉ AMACORD

Cosy restaurant with vaulted ceilings, located just across the street from the Naschmarkt. Rechte Wienzeile 15 [amacord-cafe.at](http://amacord-cafe.at)

## 5 GASTHAUS WOLF

Restaurant serving classical Viennese food. Grosse Neugasse 20 [gasthauswolf.at](http://gasthauswolf.at)

## 6 BLAUE BAR

Stylish bar in the fashionable Hotel Sacher. Ideally located for a pre-opera drink. Philharmonikerstrasse 4 [sacher.com/hotel-wien-2/kulinarik/blaue-bar](http://sacher.com/hotel-wien-2/kulinarik/blaue-bar)

Of course I'm biased, but in my opinion Vienna is one of the most charming cities in Europe. It has glorious monuments from Austria's imperial past, large public parks, and a really lively cultural scene of concerts, museums and exhibitions. It's a special place for science, as Viennese researchers have contributed to advancement in many fields.

This is evident in **KARLSPLATZ** 1, a large square in the city centre. On one side is the green area of Resselpark, named after forester and inventor Josef Ressel. Here you can find the memorial of Josef Madersperger, who invented the sewing machine. The southern side of Karlsplatz is dominated by the Vienna Technical University (TU), once home to Viktor Kaplan, who invented the Kaplan water turbine, and physicist and mathematician Christian Doppler, known for explaining the Doppler effect.

While in the area, it's also worth visiting **THE KARLSKIRCHE** 2, one of the most beautiful Baroque churches north of the Alps. Take the lift up to the church dome to see the impressive fresco by Austrian painter Johann Michael Rottmayr. I'd also

recommend taking a look at two Art Nouveau jewels: the Otto Wagner Pavilion, designed by Otto Wagner, one of Vienna's most influential architects and a visionary urban planner, and the Secession Building. The latter features one of my favourite pieces of art, Gustav Klimt's *Beethoven Frieze*.

Also in the area is the **WIENER MUSIKVEREIN** 3, where the Vienna Philharmonic's annual New Year's Day concert takes place. It's nearly impossible to get tickets for, but it's easy enough to see most other concerts. Go to a philharmonic concert so you can enjoy the glory of the Golden Hall.

My favourite place for lunch is **CAFÉ AMACORD** 4, next to the Naschmarkt, Vienna's most popular market. And the best place for Viennese food is **GASTHAUS WOLF** 5. Try the roasted calf's liver or the paprikahendl – a kind of chicken goulash.

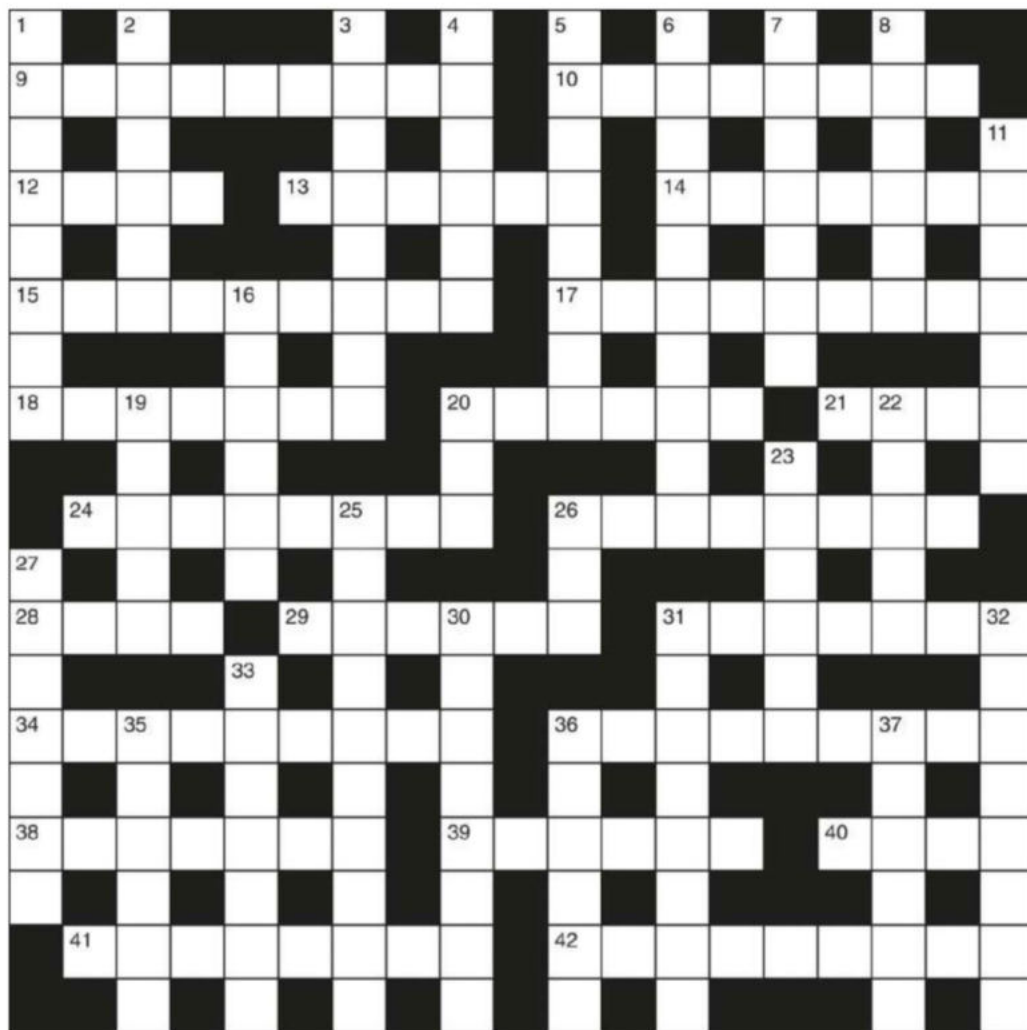
Finally, two of my favourite places for spending an evening with my husband are within walking distance of Karlsplatz: the richly decorated **BLAUE BAR** 6 in the Hotel Sacher, and the Albertina Passage, which is a restaurant with fantastic late-night entertainment. 🍷



**Sylvia Frühwirth-Schnatter** is a professor of applied statistics and econometrics at the Vienna University of Business and Economics.

# THE *BBC FOCUS* CROSSWORD

## GIVE YOUR BRAIN A WORKOUT



### ACROSS

- 9 Ruler has month to get new art current (9)  
 10 Relation moved from the east (8)  
 12 Fib about Frenchman having sharp object (4)  
 13 Buddha's attendant gives two articles to attorney (6)  
 14 Correct route planned to church (7)  
 15 Chat about taking account, with a graduate, of a resin (9)  
 17 Development of strange giant toes (9)  
 18 Aid sure to work for those that are left (7)  
 20 Time to add salt (6)  
 21 Nonentity found in daze, rocking (4)  
 24 Soldier gets graduate with old left curve (8)  
 26 Snack taken home involved mineral (8)  
 28 Our Duncan's tongue (4)  
 29 Oxygen and carbon forming neat fuel (6)  
 31 Examiner gets terribly nasty about a student (7)  
 34 Eccentric uncle has wild soul in small body (9)  
 36 Use of vaults may ruin a coat badly (9)  
 38 Progression is happening (7)  
 39 Left university and found answer in capital (6)  
 40 European barrier to cheese (4)  
 41 Beret-shaped – too weird for a vegetable (8)  
 42 Notice tuna oil generated praise (9)

### DOWN

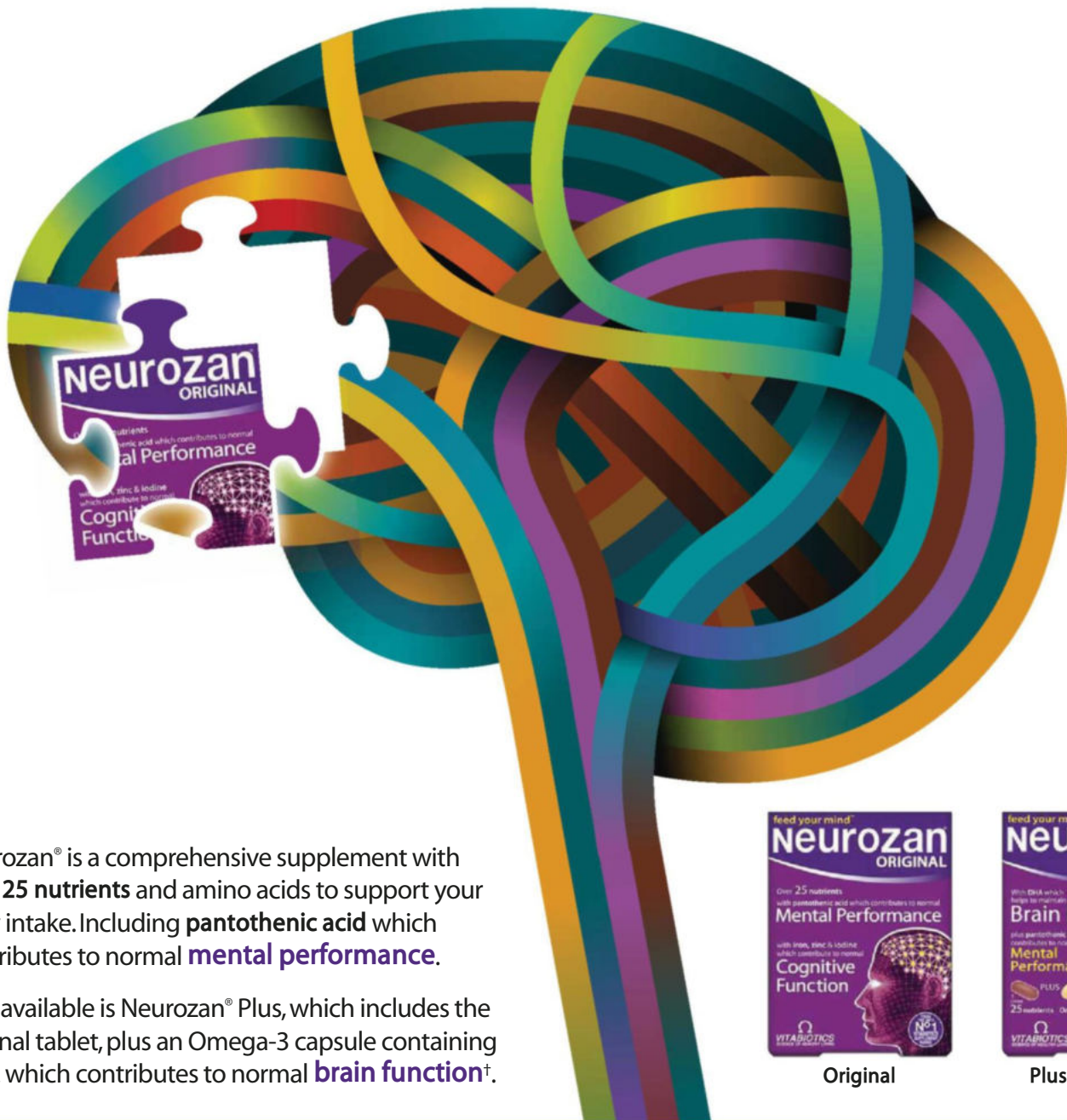
- 1 Program has mule running to a hill (8)  
 2 A cat in charge at a very small level (6)  
 3 Close friend tangled chain and tubes (8)  
 4 Developed chip with no change of sound (6)  
 5 The first stone gives soldier a pain (8)  
 6 Comic prose about scientific equipment (10)  
 7 First character at home gets one tail wagging (7)  
 8 King notes this place has one form of theatre (6)  
 11 Snow eater in a helicopter (7)  
 16 Curry may generate dramas (6)  
 19 Piece of London real estate (5)  
 20 Lose argument about the Baltic, say (3)  
 22 Guard initially lost access (5)  
 23 New aim – to get friend an antelope (6)  
 25 Kissing affects cousin a lot (10)  
 26 Insect of character, say (3)  
 27 Confront putting vase inside kiln (7)  
 30 Sailor thus finds instrument complete (8)  
 31 Pitcher-shaped leaf may aid music performance (8)  
 32 Shelter with eastern fellows in block of flats (8)  
 33 Easing of tension netted plan on energy (7)  
 35 Caught sign of progressive decay (6)  
 36 When sodium is repeatedly found in pineapple (6)  
 37 Rind is thrown at primate (6)

### ANSWERS

For the answers, visit [bit.ly/TheNumberGames](http://bit.ly/TheNumberGames)  
Please be aware the website address is case-sensitive.



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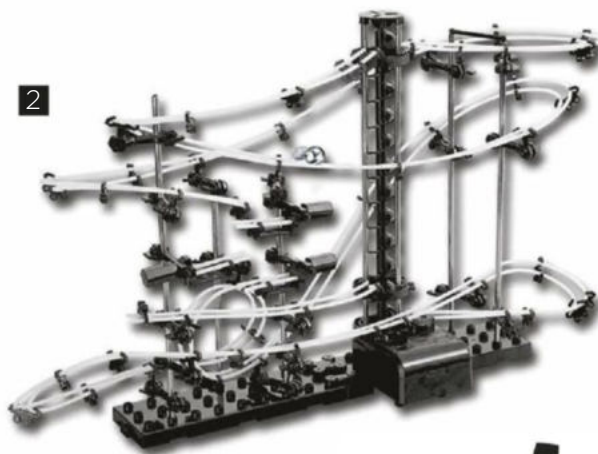


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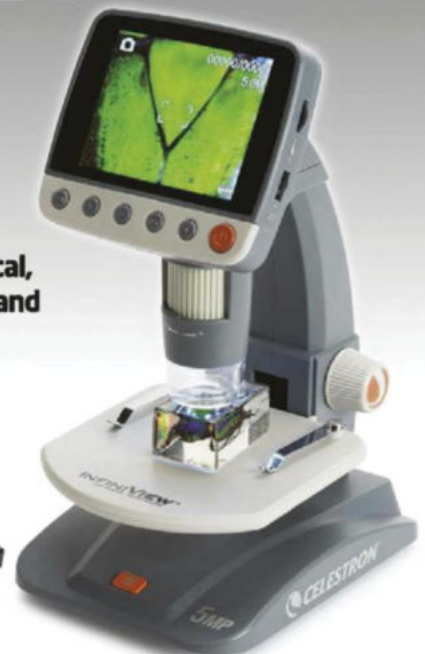
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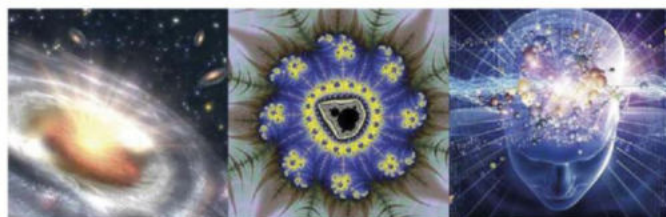
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JANUARY  
 ISSUE  
 ON SALE  
 5 JANUARY

# NEXT MONTH



## PALAEONTOLOGY

### UNSOLVED MYSTERIES OF THE DINOSAURS

We know more than ever about the dinosaurs, but there's still a great deal to learn. What colour were they, how did they learn to fly, and why did *T. rex* have such tiny arms?

## CRYONICS

### WHO WANTS TO LIVE FOREVER?

Deep within Texas, work is underway on project Timeship – an 'immortal village' that will store 50,000 frozen people with the hope of bringing them back to life. Just how realistic are its aims?



PHOTOS: GETTY X3, ALAMY

## PSYCHOLOGY

### MEET THE WORLD'S HAPPIEST PEOPLE

2016's UN World Happiness Report says Denmark is the most contented place on Earth. So just what do the Danes know that we don't?



## ENVIRONMENT

### CAN WE SAVE OUR FISH?

Poor fishing practices are putting marine life at risk. In fact, one study claimed that there'll be no more seafood by 2048. We find out what can be done to solve the overfishing problem.



# "I know of several people who have had my snowflake images tattooed onto their skin"

This Christmas **Helen Pilcher** talks snowflakes with **Ken Libbrecht**, professor of physics at Caltech

## What do you do?

I am interested in how crystals grow, so I study snowflakes. I study regular snowflakes 'in the wild', and I make designer snowflakes in the lab. What's amazing is the variety of different forms that you see.

## Do snowflakes always look like the perfect six-siders seen on Christmas cards?

Not at all. About one in a million snowflakes are like that and they only form in very specific conditions. The rest are all sorts of different shapes. At  $-2^{\circ}\text{C}$ , you get simple hexagons; around  $-5^{\circ}\text{C}$  you get columns; then at  $-15^{\circ}\text{C}$  the six-siders reappear. Sometimes a snowflake is a single crystal, other times it's a cluster of hundreds of crystals that have collided together.

## So no two snowflakes are the same?

Each snowflake experiences a range of different temperatures and humidities as it falls from the sky. This influences the way it looks. I doubt that any two snowflakes will experience exactly the same conditions as they fall, so it's unlikely that any two naturally occurring snowflakes will end up the same. But I can make identical snowflakes in the lab.

## Snowflake twins! Excellent! How do you do that?

I start by making lots of little crystals in a big tank, then place two of them side by side on a microscope slide. I then blow moist air on them to make them grow. By altering the temperature of the glass slide and the humidity of the air, I can control the shapes that form. I can make identical twins and also shapes that never occur naturally, like snow-crystal chandeliers and snowflake bouquets.

## How do you stop the snowflakes from melting while you're photographing them?

By working in the cold! And by keeping the microscope slides and objectives cold too. I've photographed thousands of snowflakes. Natural snowflakes often start to evaporate once they leave the clouds, so the edges can look a little rounded. I sometimes hang around in car parks in northern Ontario looking up at the street lamps and catching the snowflakes as they fall.

## Have you had any of your snowflakes knitted into a Christmas jumper?

I don't own an ugly Christmas sweater of any kind, but I do know of several people who have had my snowflake images tattooed onto their skin.



## What's the best snow for making snowmen?

The best snowman weather is just below zero. If it gets much colder, the snow doesn't stick. When the temperature gets to  $-30^{\circ}\text{C}$ , you get this Styrofoam-like substance that squeaks when you walk on it, but it's no good for making snowmen.

## Where else has your knowledge of snowflakes taken you?

Well... I was snowflake consultant for the Disney animated movie *Frozen*. They wanted the magic they created to have a hint of realism to it, so they asked me how their snowflakes should look. I told them they should all be six-sided. It was fun to see my name on the film's credits. ❄️

Prof Kenneth Libbrecht is a physics professor at Caltech. His most recent book is *The Snowflake: Winter's Frozen Artistry* (£15.99, Voyageur Press).

### DISCOVER MORE



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NEXT ISSUE: DANIELLE GEORGE



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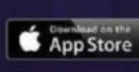
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Visible flakes seen at 2ft with regular use